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IMMUNIZATION AGAINST EAST COAST FEVER

A. D. IRVIN (Editor)

REPORT OF A WORKSHOP ON COLLECTION, HANDLING AND ANALYSIS OF PERFORMANCE AND PRODUCTIVITY DATA

Held in Nairobi, Kenya
23 - 25 September 1985

ILRAD

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PREFACE

This report publishes the proceedings of a Workshop which was held to discuss the most appropriate ways of collecting, handling and analysing data on the performance and productivity of cattle immunized against East Coast fever (ECF). The Workshop was thus a sequel to one held in 1984 in which the different methods of immunization against ECF were discussed.

Regular workshops of this kind are becoming an important means whereby different groups and countries involved in ECF immunization can keep in close contact and in this way develop, between themselves, the most appropriate methods and strategies for ECF control in different situations.

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

Grateful thanks are expressed to the Director General, ILRAD, for use of facilities, to J.K. Lenahan for help in organisation and to T.T. Dolan for help and advice during editing. The expert assistance of Mrs D. Churi and Mrs R. Aiondo in preparation of the manuscript is gratefully acknowledged.

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INTRODUCTION

A joint ILRAD/FAO meeting entitled 'Immunization against Theileriosis in Africa' was held at the International Laboratory for Research on Animal Diseases (ILRAD) in October 1984. Attention was given to methods of immunizing cattle against East Coast fever (ECF), and to identifying the needs of the various countries affected by the disease (Irvin, A.D., Editor, 1985, Immunization against Theileriosis in Africa. Nairobi, ILRAD, pp. 1-167). A specific recommendation was made in the Proceedings of that Meeting that 'immunization against ECF using infection and treatment should be implemented in the immediate future'. A number of countries now use such a procedure and it is anticipated that it will soon be adopted more widely. However, in order to gain a true picture of the impact and value of immunization under different farming situations, the 1984 meeting identified further needs:

(1) standardization of procedures, in terms of immunization strategies, data recording and follow-up,

(2) establishment of a database for recording and analysis of results.

The current Meeting was called therefore to look at these needs more closely, to assess the information from trials undertaken or completed since the last meeting, and to formulate and develop appropriate methods for the collection, processing, analysis and utilization of productivity data of immunized cattle.

By emphasising the importance of data collection and management it was hoped to assist the participants and their governments (or aid agencies) in interpreting the results of immunization trials, in providing a more objective assessment of the productivity of immunized cattle and in determining the potential economic benefits of immunization.

The meeting was divided into three main sessions. In the first session reports and results from field trials were presented; in all cases emphasis was placed on approaches to immunization and data collection and analysis rather than on specific results (see Summary of Field Reports). The second session considered in more detail design of immunization trials and programmes, and the ways different computer programmes could be used for handling, storing and processing data. At the same time, participants were given the opportunity of working with computers and handling data sets (see Appendix I). In the final session, the various aspects of performance and productivity recording and evaluation were examined, and recommendations were presented to guide those involved in ECF immunization on the best ways to design and conduct immunization programmes so that maximum information can be acquired and maximum benefits obtained.

SUMMARY OF FIELD REPORTS

The invited participants were all actively engaged in the control of ECF or its vector within Africa. Initially, attention was given to a number of trials where ECF immunization (particularly by infection and treatment) was being implemented under different conditions and in different situations. The situations covered a wide spectrum of different field programs and approaches, indicating the complexities of ECF control by immunization, but at the same time emphasizing the needs, where possible, for a common approach to data collection, processing and analysis.

The first trial discussed was one in Kenya where 80 ECF-immunized Boran steers and 80 non-immunized controls were exposed to field challenge. Each of the groups was subdivided into four parallel groups which were submitted to different tick control procedures. The comparative productivity of the groups is being compared and an economic assessment of the various management systems will be made.

An alternative approach to infection and treatment immunization was described; this involves the use of extended tetracycline antibiotic cover to protect cattle during early field challenge. While it was recognized that this method is only of value where there is consistently high challenge, its advantages are that virtually no back-up or professional services are required, it is easy to apply, and cover may also be provided against other tickborne diseases.

Two large-scale extension trials in *Theileria parva lawrencei* enzootic areas of Kenya were considered. In the first trial, 400 Boran heifers were immunized with a locally derived composite stabilate, followed by treatment with either long-acting tetracycline (day 0) or parvaquone (day 8 after stabilate). Immunized cattle were maintained under different tick control procedures for a year. Production parameters were measured and disease incidence recorded. Immunized cattle were successfully maintained under high *T p lawrencei* challenge, but the incidence of other tickborne diseases, notably anaplasmosis, increased as the dipping intervals were extended. There were no significant differences between parvaquone or tetracycline-treated cattle in mortality or general disease incidence. The second large-scale trial was conducted in an area with both traditional pastoralist and ranch management systems. Initial baseline data on disease epidemiology was obtained and cattle were subsequently immunized with two locally-derived stabilates using a range of treatment regimes. The efficiency and costs of the different systems were compared. Excellent protection was obtained and productivity achieved for ranch cattle under different levels of acaricide cover, but performance of cattle under traditional management was less satisfactory due to massive tick and disease challenge, and management problems.

The programme in Malawi, using a mixture of defined T parva stocks (Muguga cocktail) to immunize cattle against ECF, has unfortunately been curtailed due to the completion of the joint National/FAO/DANIDA project. It is hoped that ECF immunization in this country will soon be revived. In the meantime it is encouraging to note that over 620 cattle have been immunized, distributed to smallholder farmers and are being followed-up in the field. The need to maintain the impetus of this work in Malawi is very important.

The Muguga cocktail has been used for immunization of cattle in Zambia, but the effects of immunization cannot yet be judged because of the low and irregular challenge that has been experienced on exposure of cattle in the field.

The performance of cattle under different levels of tick (Rhipicephalus appendiculatus or Amblyomma hebraeum) infestation has been examined in experimental and field situations in areas of Kenya, Zambia and Zimbabwe, where effects of disease have been controlled or eliminated so that the performance parameters which have been measured reflect primarily the effect of the ticks themselves. Data on tick feeding, cattle weight gain and performance have been collected. These studies will provide data on the effects of tick infestation in different cattle systems so that economically and ecologically acceptable methods of tick control can be formulated.

PLANNING EAST COAST FEVER IMMUNIZATION PROGRAMMES AND DATA RECORDING

The infection and treatment method of immunization against ECF is described in detail in the Food and Agriculture Organisation Handbook on "Ticks and Tick-borne Disease Control" (FAO, Rome, 1984 pp 457-507). This method is now being used in a number of field situations (see Summary of Field Reports), but in order to maximise its effectiveness and impact the current Meeting identified a number of areas where particular attention is required as the immunization method becomes more extensively applied in the field. These are described below:

1. IMMUNIZATION PROCEDURE AND CONSTRAINTS

Infection and treatment is an effective method of immunization against ECF but as it becomes applied more extensively in the field its use must be closely controlled and monitored, at least in the initial stages of its use.

It is essential that proper planning takes place before immunization is carried out, whether it is an experiment, a field trial with appropriate controls, a pre-extension trial with limited controls, or the application of a vaccine in a national disease control scheme. Planning must include the capacity for data collection and analysis. Before undertaking immunization adequate funding, equipment, consumables, facilities and staffing must be available.

A decision has to be made whether to use local isolates, a centrally prepared isolate(s) or a combination of isolates originating from another country.

The age at which immunization is applied and the need to re-immunize will be dictated by management and experience, but it has been shown that calves can be immunized as early as one month. Reduction in tick control frequency may be used to boost immunity. Seasonal variation in challenge may influence the timing of immunization.

Recommendations

i) Planning

Planning of immunization should involve consultation with statisticians and economists on the design and data recording for analysis.

ii) Parasite stocks for immunization

Well-characterized stabilates (for example, Muguga cocktail) should be used for immunization in the field. The extent of the

area in which the stabilate(s) will be used should be decided by the national government based upon epidemiological information. Isolation of local stocks, especially breakthrough strains, should be encouraged for further characterization, determination of their immunological relationship to the immunizing stock(s) and their potential use for immunization.

Original isolates should be preserved as reference stabilates. These stabilates should be used to prepare sequential bulk working stabilates with minimal manipulation to avoid parasite selection.

Immunizing stabilates must be characterized by testing for infectivity and drug sensitivity. Their monoclonal antibody profile should be determined.

A standard procedure for safety testing of stabilates for immunization should be adopted. It should include screening for viruses and other pathogens.

Infection rates in ticks used for preparation of bulk stabilates should be determined.

Studies should be carried out on the loss of infectivity of stabilates after thawing and on their long-term deterioration in storage. All stabilate information should be properly recorded.

iii) Immunization procedure

Only healthy animals should be immunized and, if practical, animals should be tested for antibodies to *T parva* and other tickborne diseases before immunization.

The extent of the area in which local isolates will be used should be determined.

Initially, immunization should be carried out to protect high producing cattle in risk areas. This should include cattle belonging to small holder dairy farmers. As immunization becomes more widely available, cattle in other sectors can be immunized.

The effects of immunization on fertility, pregnancy and milk production should be investigated taking into account the effects of both stabilates and drugs.

2. PROBLEMS OF TRIAL MANAGEMENT AND DATA COLLECTION

Successful trials and immunization programs depend on careful planning, constant monitoring during the application phase, effective reporting and analysis of results, and a follow-up phase to assess the long-term effects of immunization.

Recommendations

i) Planning and sampling

The frequency of sampling should be determined by the data required, the costs of data recording and the stresses caused to cattle through excessive sampling. Once established, the sampling protocol should be strictly adhered to as the omission of data causes serious problems in analysis.

Data should be accurately recorded on data sheets following a set sampling procedure. Duplicates should be made to insure against loss. It is better to monitor a limited number of cattle well than a large number badly.

The reliability of data recording should be closely monitored. A high degree of precision is required with the recording of data such as liveweight. Cattle scales should be regularly calibrated and serviced. If possible, electronic scales, which are portable and accurate, should be used.

ii) Management

It is important to establish effective working relationships between the trial manager and project staff, and to ensure the motivation of the staff. Effective communication between the laboratory and the trial site is essential, particularly with regard to disease diagnosis.

Unanticipated problems can be caused by drought and concurrent infections, especially with other tickborne diseases. Cattle in ECF immunization field trials may need to be immunized against other tickborne diseases, such as babesiosis, anaplasmosis and heartwater (cowdriosis).

In southern Africa where there is a seasonality in the lifecycle of the vector it is important to ensure that there is adequate disease challenge during the trial period.

iii) Data sheets

A set of data sheets was designed by a sub-committee appointed by the Meeting. Examples of these sheets are shown in Appendix II. In order to obtain uniformity in recording and analysis of data it is recommended that these sheets be used in immunization trials.

3. DATA COLLECTION - DESIGN AND ANALYSIS

The collection and analysis of data are of great importance. The data can be used to evaluate the immunization procedure scientifically and to assess the productivity associated with field immunization programmes. If an integrated approach to control of tick-transmitted diseases is to be adopted, more extensive data on tick challenge will be needed.

The information priorities for economic analysis are: the production effects of immunization using different techniques, and the production effects of tick control policies in immunized cattle. These will need to be estimated for each production system under consideration. If these effects are estimated in terms of their impact on production parameters, then the effect on production efficiency can be calculated from a productivity index which can be considered, in economic terms, from the point of view of the farmer or the nation.

Recommendations

i) Data collection and analysis

Researchers preparing experimental designs are recommended to seek professional advice on preparing a suitable protocol before experiments are conducted, and so avoid problems of generating data which cannot be analysed.

Livestock productivity indices should be evaluated with a view to selecting a standard for use in economic assessments of ECF immunization.

Where trials of the effects of ECF immunization or tick control on production are performed, estimates of all production parameters used by the productivity index should be obtained, not just those that might be affected by the tick or tickborne disease constraint. Where estimates of other production parameters are not already available, sensitivity analysis with a productivity index can identify the most important parameters.

Preliminary evaluations using 'worst' and 'best' case assumptions can be used to identify production systems in which immunization might be worthwhile. Experimental work and trials should be directed on the basis of such preliminary evaluations.

The design of experiments and trials should be kept as simple as possible; for example, if the effect of immunization *per se* is not of interest in a trial of tick control policies in immunized cattle, then non-immunized controls are not required. If designs are too complex there is a danger that the whole experiment may fail.

Excessive handling of experimental animals is likely to affect their performance, making them atypical of the population under study.

Large-scale immunization schemes should have a component designed to monitor productivity and detect problems which could arise during the program. These can then be investigated by further experimental work.

Frequent interim analyses should be conducted so that early recognition of unexpected events can be recorded and any necessary interventions carried out.

ii) Data Handling and processing

ILRAD should become the centre for computerized storage and software development of data records during the development stages of immunization programs. This would require due consideration to the reliability and confidentiality of the data sets. Once suitable software systems are available to handle ECF immunization databases, computer training should be considered.

4. IMPACT OF IMMUNIZATION ON TICK CONTROL

As immunization programs develop, tick control practices can be modified but, initially, careful monitoring of tick levels and their impact on the host, is required. As appropriate data is obtained, recommendations can be made regarding alteration of tick control practices.

Recommendations

i) Tick identification and counting

Experiments require the accurate identification, by a reliable worker, of the tick species involved, as the easily-confused rhipicephalid species may be present. The data should come from initial half-body collections from 5 to 10 animals.

Tick counts should be made from half the host body, with separate counts of the ear ticks, thus taking account of ECF and non-ECF vector species which could affect overall productivity.

If possible, male/female/standard female data should be obtained; this can be obtained from periodic half-body collections from the same animals chosen initially from a random sample of the cattle.

Tick counts should be made at a maximum of once per week or a minimum of once per month.

The host sample size should be determined following a statistician's advice based on local conditions.

Tick numbers should be assessed by a rapid rating by a trained observer on half the body. A possible rating for total ticks would be: 1 = 0-10; 2 = 11-50; 3 = 51-250; 4 = 251-750; 5 = greater than 750. A similar rating on a generic basis could be devised.

Ticks should be rated monthly if possible (this is a minimum in Central/Southern African countries with strict seasonality of tick infestation).

ii) Tick control

Tick control regimens in ECF immunization trials should take into account the likelihood that tick numbers tolerated by cattle owners will increase greatly when the tickborne disease problem has diminished after immunization programs.

In principle, control should be at three levels of intensity, that is, complete, moderate or none. In practice, this might mean control twice weekly, once every 3 to 4 weeks, or never. Under strict seasonality conditions, moderate control should be at 2 to 3 week-intervals for the season of adult tick abundance. This can be modified such that the moderate intensity control is based on a pre-determined tick infestation threshold. The threshold should be

a group mean infestation likely to cause slight damage, i.e. at least a total of 100 adults per side of the host. A comparison of results obtained from the 'moderate' and 'never' tick-controlled groups should allow acceptable minimal tick control regimens to be determined.

If past experience is favourable the 'complete' regimen can be omitted. Alternatively, if other tickborne diseases are feared, the existing tick control intervals should be progressively doubled with conservative time steps, provided there is no unacceptable increase in tickborne disease incidence.

Novel methods of tick control can be included in trial procedures where appropriate.

5. FUTURE PROPOSALS AND RECOMMENDATIONS

Immunization against ECF must form part of integrated management strategies. Before tick control policies can be radically changed, immunization against anaplasmosis, babesiosis and cowdriosis must be considered where these diseases are a problem. Some immediate reduction in tick control intensity should be possible; further reduction would be dependent upon the establishment of the economic threshold for each particular situation.

Epidemiological data, as well as long-term animal production data, is needed to develop and test models for disease and production modelling. Important features of both the epidemiology of theileriosis and immunization are (1) occurrence of antigenically distinct strains, (2) duration of immunity in different situations and (3) age susceptibility and immuno-competence.

Recommendations

i) Application and impact of immunization

Immunization against ECF should form part of an integrated program which includes tick control, chemotherapy and management.

The possible effect of immunization in modifying the epidemiology of ECF and other tick-borne diseases, should be closely monitored.

Large-scale pre-extension immunization trials at the farm/ranch level should be implemented coupled with long-term monitoring of immunized animals.

Improved methods of immunization against all tickborne diseases should be developed.

ii) Collaboration

ILRAD should play a major role in strain identification and collaborate in the development of models for epidemiology and monitoring animal production, as well as in data processing and analysis.

Close collaboration between all disciplines should be maintained with full participation of national staff in all aspects of immunization programs. Provision should be made for formal and inservice training of national staff.

At the Second Annual Review of the FAO/DANIDA program for tick and tickborne disease control in East and Central Africa it was proposed that a meeting be held in October 1986 in Addis Ababa, to examine in detail the economic aspects and the effects of ticks and tickborne diseases on productivity of cattle. This proposal is supported.

Appendix I

DATA MANAGEMENT FOR THE EVALUATION OF PERFORMANCE AND PRODUCTIVITY OF CATTLE IMMUNIZED AGAINST EAST COAST FEVER

G.Gettinby and A.D.James

INTRODUCTION

Over the last decade, laboratory and field experiments have shown that cattle can be successfully immunized against ECF using the infection and treatment method (Irvin, 1985). It is expected that extensive field immunization programs will soon be initiated. These programs should provide data on immunized and non-immunized cattle from herds in Central and East Africa where ECF is endemic. This data will form the basis for the economic assessment of the impact of immunization. Detailed immunization records can identify important factors influencing the efficacy of the procedure. Identification of these factors may highlight needs for further experimental research. Production records will enable productivity indices to be determined and field challenge records will allow quantitative epidemiological models to be formulated. In this way a valuable database can be established. The competent management of such a database is important if the objectives are to be achieved.

DATA COLLECTION

Data collection systems for animal disease parameters have been pioneered by several organizations in Africa. In particular, the International Livestock Centre for Africa (ILCA) has acquired a great deal of expertise in assessing animal productivity. Trail et al. (1979, 1985) have described systems used in the study of the relationship between trypanosomiasis and cattle productivity. Although an ECF immunization program deals with the transfer of a technical process into operational field situations there are many similarities with the studies on productivity under trypanosome challenge. Data collection consists of accumulating records of individual animals from different geographical sites. Each record will have many 'fields' associated with it such as breed, type of farm, stabilate used etc. Each field can be regarded either as a factor or a variable depending on the hypotheses of cause and effect under examination. Fields can be loosely divided into four categories.

(1) Site fields. These are fields which specify the site and animal to be included in the study, and are normally factors and not variables.

Factors are: country; site; owner; farm type; experiment number; code number; animal number; breed; sex; date of birth.

The animal number can be a key field for the identification of all other fields associated with an animal.

(2) Immunization fields. These fields contain all data associated with the infection and treatment immunization procedure.

Factors are: immune/control status; date of immunization; stabilate used; site injected; volume of stabilate; drug used; date drug given; doses given; date of challenge.

Variables are: clinical symptoms after immunization; serology after immunization; clinical symptoms after challenge; serology after challenge.

(3) Production fields. These fields establish the productivity of immunized and control animals.

Factors are: initial weight; reproductive status; service.

Variables are: mortality; liveweight change; milk production; calving; fertility.

(4) Natural challenge fields. These fields report periodically on the response of animals to changing environmental conditions.

Factors are: diseases present; treatments administered; tick activity; tick controls; weather.

Variables are: serology; packed cell volume (PCV); tick infestation.

Using records of the above fields, the performance and productivity of immunized and non-immunized cattle can be statistically evaluated based on specific variables such as:

cow mortality rate at age 2,3,.... years
cow liveweight at age 2,3,.... years
milk yield at 1st, 2nd, ... lactation
lactation completion rate
incidence of abortion
incidence of fertility
calf liveweight gain at age 1 year
calf liveweight at age 1 year
calf mortality rate at 1 year
clinical response to immunization
Indirect Fluorescent Antibody (IFA) titre after immunization and after challenge
PCV after immunization
clinical response to field challenge
PCV under field challenge

PCV may not be directly relevant to ECF but may indicate the presence of other diseases such as helminthiasis or trypanosomiasis

ANALYSIS OF DATA

Statistical methods of analysis.

The choice of statistical method will depend on the inferences made from the data collected, the volume of data generated, and the frequency with which interim analyses are required. An important distinction occurs depending on how the data are collected. This distinction can be relevant to the analysis. An experiment is undertaken in cases where animals are randomized to specific groups such as immunized and non-immunized, or drug treated and control, in order to test hypotheses. The randomization is usually based on factors such as sex, age, weight etc. In contrast, the rigorous demands of an experimental design are often not possible in the field and data are collected by surveillance. In the past, most immunization studies have used an experimental procedure designed and implemented according to a strict protocol, whereas productivity studies have been based on surveys.

In designed experiments, confirmatory statistical techniques are used for tests of significance for site, group differences etc. This usually presents no difficulties as there are few missing data and the design ensures that, animal numbers, for example, are 'balanced' within groups. One of the most widely-adopted experimental designs consists of randomizing animals to two or more groups of interest and collecting sequential observations from each animal at the same time. This is known as a two-factor experimental design with repeated measures. One factor is associated with the treatment groups and the other is associated with time. Since the animals are the experimental subjects, account must be taken of the repeated time measurements on individual animals. Using analysis of variance this particular factorial design can be used to test for: (1) significant group X time interactions, which indicate that groups do not respond similarly over time, (2) significant differences between treatment groups, and (3) significant differences between times. Only the first two of these tests are generally of interest and normally the presence of a significant group X time interaction precludes analysis for significant group or time differences. Winer (1971) gives details and examples of this useful experimental design.

Similarly, confirmatory statistical testing methods can be applied to survey data but this often requires 'least-squares' algorithms to calculate the statistics. This more complex procedure is needed to take account of missing data or treatment combinations which have unequal numbers of animals etc. Harvey (1960) described an algorithm which has proved satisfactory for such analysis (Trail et al., 1979). A computer software program known as GLIM (supplied by Numerical Algorithms Group, Oxford, UK) offers an alternative procedure. However, the implementation and interpretation of the results from least-squares algorithms are not always straightforward.

Recently, Exploratory Data Analysis (EDA) techniques have emerged as a complementary approach to confirmatory statistical techniques. They emphasize the value of exploring data to set up hypotheses using summary statistics often expressed in graphical

form. For example, histograms are replaced by 'stem-and-leaf' plots which are easier to create. The convention of plotting means and standard deviations on graphs is replaced by more informative 'box-plots with whiskers'. These techniques are described by Tukey (1977) but the novice should consult Erickson and Nosanchuk (1979) for a readable and simple introduction. The EDA techniques are particularly suitable for interim analyses of on-going studies and generally they do not involve tedious calculations or rigorous tests of significance.

The analysis of both experiments and surveys usually takes place at the end of the study. However valuable information can often be overlooked if interim analyses are not undertaken. An ECF immunization program should have monthly interim analyses on data from individual sites using summary statistics such as those described in EDA techniques. (Interim analyses also have the advantage of sustaining momentum and interest in the project). Thereafter, at 6-month or 1-year intervals, confirmatory statistical methods could be exploited to identify differences between groups and to generate production indices.

An important point to remember is that statistical significance does not always equate with biological significance. Before analysing for differences between groups a useful magnitude of difference should be prescribed.

Data management systems.

Microcomputers offer sufficient storage facilities to cope with the storage, retrieval and analysis of large volumes of data. Management of the data within the computer can also be handled using software programs. Some software programs which are potentially suitable for recording data from an ECF immunization program are:

PANACEA - a database system designed for the management and statistical analysis of livestock data (James, 1985).

dBASE III - a data management program which allows records to be manipulated using a procedure language. Recent developments at ILCA suggest that an extension to this package, which is specifically tailored for recording and analysing animal productivity data, will soon be available.

SYMPHONY LOTUS - a widely used package which offers record management, spreadsheeting, wordprocessing and graphics.

SMART - a more recent package, similar to SYMPHONY, which allows flexible transfer of information between spreadsheet, database and wordprocessor, and requires little program storage allowing more data records to be stored.

An efficient way to study data arising from an ECF immunization program would be to develop a central ECF software program based on one or more of the above programs. Thereafter the software could be made available to research centres interested in carrying out analysis of data on site.

PRODUCTION INDICES

A cattle production system converts feed and other inputs into a number of offtake products. The size of the herd may increase, but this can be considered as a type of product. The various inputs and outputs can be given economic values so that total input and output can be compared to give a measure of economic efficiency. Efficiency can also be considered in other terms. For example, ecologists might give energy values to the inputs and outputs to estimate energetic efficiency.

Production constraints affect the efficiency of conversion of inputs to outputs. If there is a constraint to production, the system is likely to produce less output per unit of input. This represents the cost of the constraint. In practice, it is difficult to estimate directly the effect of constraints in these terms. In particular, the valuation of inputs that are not bought and sold, such as common grazing, can present many problems.

A wide range of measures of cattle production efficiency are used. Production parameters, such as calving rate and age at maturity, are measures of technical efficiency in one aspect of the production system. They allow easy comparisons of the efficiency of different herds or production systems in that particular respect, without the complication of other factors. Most production parameters are easier to estimate than more general measures of efficiency of production, such as the value of total production per cow, or per animal.

In the evaluation of animal health constraints, there are difficulties in the use of many of the standard indices of efficiency. For example, expressing the effect of a health constraint in terms of production per cow is very confusing when the proportion of cows in the population is likely to change as a result of the removal of the constraint.

The static livestock model.

James (1984) used the total value of output per livestock unit equivalent (LUE) of feed supply as a measure of livestock production efficiency for the evaluation of animal health constraints. If this system is used, no problems arise from changing herd structures or population sizes associated with changes in animal health. A system of equations allowed the expected value of output per LUE from a set of well-known and easily estimated production parameters to be calculated. The system of equations was called the Static Livestock Model, because it described the situation where offtake was at such a level as to produce a constant herd size. However, the model also shows the potential rate of population growth if offtake is diverted for this purpose, so the term 'static' may be rather misleading.

The model can be used to evaluate the economic effect of disease control. The model is run twice, using estimates of the production parameters with and without the disease. The difference

in the value of output represents the economic benefit of control. This can be compared to the cost of the control program. It is much easier to estimate the effect of a disease on production parameters such as mortality rate and lactation yield than it is to estimate the effect on output directly. If the calculations are made on a microcomputer, they take less than a second, and so sensitivity analysis can be used to test the effect of errors in the production parameter estimates. This also helps to concentrate data acquisition resources on the most important areas of uncertainty.

Some animal health constraints, such as tick infestation, cause producers to adopt an entirely different production system to the one they would use without the constraint. The model can be used to compare the efficiency with which the two systems would use the same feed resource. However, in such an analysis, it is necessary to take into account other inputs that might change, such as fencing, buildings etc.

The main problem in the use of the model is that the mean feed requirement of each type of animal must be given in livestock units. This can be difficult to estimate on a consistent basis. Moreover, the feed requirement is not independent of other production parameters. For example, if the calving rate increases, cows will have more calves and lactations, and this will increase their mean feed requirement. The original system of equations did not take such interactions into account, and adjustments had to be made manually.

The Cattle Production Efficiency Calculator (CPEC).

The Static Livestock Model can be modified to overcome some of the above difficulties and the modifications have introduced some elements that are specific to cattle. The CPEC system estimates feed requirements in megajoules of metabolizable energy (ME) per day according to the estimates used in formulating rations, but without 'safety margins' (Ministry of Agriculture, Fisheries and Food, 1975). The mean ME requirement of each class of animal is calculated on the basis of liveweight, rate of liveweight gain, pregnancy rate and milk production. Allowance is made for the energy concentration of the feed: bulkier feed requires more energy for digestion. The mean ME requirement of each class of animal is adjusted automatically for changes in production parameter values.

Data required by CPEC are:

(1) Mortality rates for each class of stock: the classes considered by the model are breeding cows, breeding bulls, replacement heifers (up to first calving), replacement bulls, surplus heifers and surplus males (steers or fattening bulls). Surplus heifers are handled separately because in some systems they are managed separately. If they are managed in the same way, then the same parameters would be used. A separate survival rate is used for calves up to weaning, as mortality rates in young calves may be higher than for older animals.

(2) Culling rates for breeding cows and bulls. This is a management variable, and it will determine the availability of surplus young stock for offtake or increasing the herd size.

(3) Weights at birth and maturity determine the feed requirement for growing stock, taking into consideration the age at maturity. Rapid growth requires more energy per kilogram liveweight gain.

(4) Age at maturity is used to calculate rates of liveweight gain, and to determine the number of young stock needed as replacements.

(5) Cow/bull ratio is the only herd structure parameter required. The value will be high if artificial insemination is used.

(6) Calving rate is the normal measure of fertility in cows. Heifer fertility is reflected in the age at maturity.

(7) Percentage of replacement heifers remaining barren may be used where replacement heifers are managed differently from surplus heifers. The number of replacement heifers kept may be more than the number required to maintain the herd if some of them fail to calve.

(8) Milk offtake per lactation excludes that used by calves; it should be the quantity available for sale or human consumption.

(9) Megajoules per kilogram of milk produced varies with the composition of the milk. Standard tables are available (Ministry of Agriculture, Fisheries and Food, 1975).

(10) Energy concentration of feed (MJ/kg) is required to calculate the energy used in digestion. Standard tables of energy concentration are available (Ministry of Agriculture, Fisheries and Food, 1975). Weighted average values should be used for mixed feeds.

(11) Offtake values are used to convert physical production into economic terms. If energy values of offtake were used, the system would measure energetics, instead of economic, efficiency.

The efficiency of production is expressed as the value of output per unit of feed supply. The unit of feed supply is standardized as a feed supply yielding 100 MJ of ME per day. This is approximately the requirement of a high-yielding dairy cow. If required, the production per animal can be estimated, as the numbers of each class of stock per unit of feed supply are calculated. The potential herd growth rate can be estimated by dividing the surplus heifer offtake by the number of breeding cows per unit of feed supply.

The system is primarily intended for national planning activities, rather than as a model application to individual herds. Accordingly, no provision is made for stochastic analysis; all output is expressed as long-run expectations.

The microcomputer program offers a sensitivity analysis facility. For each parameter, the percentage change in value of output caused by a percentage change in the parameter value is calculated. This figure is calculated for a range of changes in parameter values to show any non-linearity of response. Chema et al. (1985) give an example of the application of CPEC.

QUANTITATIVE MODELS

The concept of modelling is not new to ECF studies. Jarrett et al. (1969) modelled the kinetics of replication of Theileria parva infections in cattle challenged with infected Rhipicephalus appendiculatus ticks. These infectivity studies were continued by Radley et al. (1974). Since then epidemiological models of tick activity have been formulated by Gardiner et al. (1981) and Gardiner and Gettinby (1983) for Ixodes ricinus based on biological development rates, and by Sutherst et al. (1979) and Utech et al. (1983) for Boophilus microplus based on larval survival. It should be possible to model the lifecycle of R appendiculatus using these techniques. The literature on the dynamics of T parva infections in cattle and tick hosts can be exploited to complement the tick-activity model and so provide a useful model of disease transmission. Since animals immunized by infection and treatment often have carrier status, modelling disease transmission remains important. However, epidemiological models require extensive data on environmental factors if they are to be validated.

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Appendix II

DATA SHEETS FOR RECORDING RESULTS OF IMMUNIZATION TRIALS - PROPOSED FORMAT.

Sheet 1	Entry sheet for control and immunized cattle.
Sheet 2	Productivity record sheet.
Sheet 3	Event sheet.
Sheet 4	Clinical record and post mortem sheet.
Sheet 5	Climatic data - monthly record sheet.

EAST COAST FEVER IMMUNIZATION ENTRY SHEET FOR CONTROL AND IMMUNIZED CATTLE

COUNTRY SITE OWNER EXP. NUMBER SHEET NO. OF

RECORDER NAME(Print) SIGNATURE DESIGNATION

FARM SIZE/TYPE	DAIRY	BEEF
LARGE		
MEDIUM		
SMALL		

STABILATE(S) USED FOR IMMUNIZATION						
NAME	NO.	SOURCE	VOL.	DILN	SITE	DATE
1						
2						
3						

DRUG USED AT TIME OF IMMUNIZATION			
NAME	DOSE mg/kg	SITE	DATE
1			
2			
3			

DATE OF IMMUNIZATION (DAY 0) DATE EXPOSED TO FIELD CHALLENGE EXPOSURE DAY

ANIMAL NUMBER	BREED	SEX	WEIGHT (kg)	DATE OF BIRTH	DATE OF LAST CALVING	NUMBER OF CALVINGS	LAST CALF		IMM OR CTRL	REACTION TO IMMUN.			CLINICAL REACTION	T.PARVA SEROLOGY (Day)						REMARKS
							ID.NO.	SUCKLING		TEMP	SCHIZ.	PIRO								

EAST COAST FEVER IMMUNIZATION PRODUCTIVITY RECORD SHEET

DATE SITE OWNER EXP. NUMBER SHEET NO. OF

RECORDERS NAME (Print) SIGNATURE DESIGNATION

PASTURE DATA	GOOD	MEDIUM	POOR
QUANTITY			
QUALITY			

WATER AVAILABILITY

TICK RECORDING METHOD						
TYPE OF COUNT	COUNT ACCURACY* AND SPECIES					
HEAD						
½ BODY						
WHOLE BODY						

*E=ESTIMATE C=COUNT P=COLLECTED AND PRESERVED

TICK CONTROL
1. DIP/RACE/HAND SPRAY/GREASE/OTHER (specify)
2. ACARICIDE USED
3. FREQUENCY OF APPLICATION (specify)

ANIMAL NUMBER	WEIGHT kg	MILK kg	CALF AT FOOT	TICK NUMBERS (specify species)						SEROLOGICAL TITRES						PCV	REMARKS
										T.p.	T.m.	Bab	Anapl.				

EAST COAST FEVER IMMUNIZATION - EVENT SHEET

ANIMAL NUMBER	DATE	SITE

FEMALE CATTLE (give dates)

SERVICE	CALVING	DRYING OFF

CALF DATA

NUMBER	BIRTH DATE	SEX	WEIGHT	SIRE BREED

DISEASE OCCURRENCE (details on separate sheet) DIAGNOSIS	DURATION	OUTCOME

DRUG TREATMENTS

DRUGS USED	ROUTE	VOLUME	DATE

SURGICAL TREATMENTS (define with dates)

DISPOSAL METHOD	DATE	CARCASE VALUE

EAST COAST FEVER IMMUNIZATION - CLINICAL RECORD & POST MORTEM SHEET

ANIMAL NUMBER DATE SITE

RECORDERS NAME SIGNATURE DESIGNATION

CLINICAL RECORDS

CONDITION/APPEARANCE TEMPERATURE (°C)

APPETITE CONSTIPATION

RESPIRATION DIARRHOEA

NASAL/OCULAR DISCHARGE LYMPH NODES

LOCOMOTION SIGHT

OTHER MILK YIELD

SAMPLES COLLECTED

BIOPSIES

BLOOD slides/sera/haematology/PCV

FAECES

OTHER

POST MORTEM DETAILS

CARCASE APPEARANCE/SKIN/FAT

MUSCULO/SKELETAL SYSTEM

MOUTH/NOSE

EARS/EYES

THORACIC CAVITY

RESPIRATORY SYSTEM

CARDIOVASCULAR/HEART

DIGESTIVE TRACT

LIVER/GALL BLADDER

SPLEEN

KIDNEYS/URINARY

LYMPHATIC SYSTEM/BLOOD

REPRODUCTIVE ORGANS

CENTRAL NERVOUS SYSTEM

OTHER

EAST COAST FEVER IMMUNIZATION
CLIMATIC DATA - MONTHLY RECORD SHEET

SITE MONTH YEAR

EQUIPMENT USED LOCATION OF EQUIPMENT

DATE	RAINFALL(mm)	TEMP°C		TEMP°C		TIME OF RECORDING	RECORDER SIGN
		MAX	MIN	WET	DRY		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
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31							

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