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**ITVM**

FINAL REPORT

211d GRANT

GRANT TITLE: "Expanding Competence in the Design and Execution of Livestock Development Programs in the Tropics, Emphasizing Ruminant Livestock Production Systems Through Improved Breeding and Disease Control"

SUBMITTED TO:

Livestock Division  
U.S. Agency for International Development  
U.S. Department of State  
Washington, D.C.

by

Institute of Tropical Veterinary Medicine  
College of Veterinary Medicine  
Texas A&M University  
College Station, Texas 77843

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FINAL REPORT  
211d Grant

Grantee: Texas A&M University  
College Station, Texas

1/2 to Institute of Tropical Veterinary Medicine, and  
1/2 to Animal Science Department

This portion of the report is concerned with the activities of  
the Institute of Tropical Veterinary Medicine (ITVM).

Summary

Period of Grant: 1 July 1972 - 30 June 1977 (extended, in part,  
to 31 December 1977)

Amount of Grant: \$250,000 (\$50,000/yr)

Director, ITVM: Dr. Fred D. Maurer -- 1 July 1972 - 31 May 1976

Dr. Gilberto S. Treviño -- 1 June 1976 - 30 June 1977

## ITVM FACULTY AND SUPPORT PERSONNEL

The faculty at ITVM has experienced steady turn-overs. It seems reasonable to list all the personnel who have served on the staff, with the period of their service in parentheses:

### Professional:

Fred D. Maurer, D.V.M., Ph.D. - Director (1966-76)  
Gilberto S. Treviño, D.V.M., Ph.D. - Director (1976- )  
Kenneth L. Kuttler, D.V.M., Ph.D. - Assoc. Director (1966-78)  
G.L. Boring, D.V.M., M.S. - Assoc. Director (1977)  
R.A. Todorovic, D.V.M., M.S. - Assoc. Professor (1969- )  
L.G. Adams, D.V.M., Ph.D. - (1972-74)  
T.M. Craig, D.V.M., Ph.D. - (1973-74)  
J. Wyss, D.V.M., Ph.D. - (1972-74)  
T.J. Galvin, D.V.M., Ph.D. - (1969-72)  
D.E. Corrier, D.V.M., Ph.D. - (1974-77)  
K.C. Thompson, D.V.M., Ph.D. - (1973-78)  
Dave Hopps, D.V.M., Ph.D. - (1973-76)  
L.L. Logan, D.V.M., M.S. - (1976- )  
G.G. Wagner, B.S., Ph.D. - (1977- )  
E. Gonzalez, D.V.M., M.S. - (1973-78)  
M.K. Terry, D.V.M. - (1976-77)  
Ms. Pat Holman, B.S., M.S. - (1977- )

### Administrative Support Personnel:

Mr. H.E. Welch, B.A. - Ass't. Director for Administration (1977- )  
Ms. Diane Moore, Senior Secretary - (1976- )  
Ms. Laura Malloy, Secretary ( 1978 )

Technical Support Personnel:

Ms. Jan Henson, Technician I - (1972- )

Ms. Karen Egg, Technician I - (1977- )

Ms. Yolanda Oliver, Histopathology Technician - (1978- )

Mr. Ray Long, Research Assistant - (1970- )

Animal Caretakers:

L.W. Johnson

Henry Wittner

Robert Stevens

David Cruz

ITVM FACULTY AND SUPPORT PERSONNEL

## OBJECTIVES

INSTITUTE OF TROPICAL VETERINARY MEDICINE

211d

Objectives:

1) To develop staff expertise in designing and implementing comprehensive animal health research programs for ruminant production in tropical developing countries.

2) To provide members of the staff for work abroad in a triadic mission of research, diagnosis, and training of animal diseases endemic to tropical developing countries.

3) To provide technologic transfer at postgraduate levels by programs designed for fulfilling course work on campus and problem work abroad.

Resources to carry out objectives:

I. Main Campus Administrative Office and Principal Laboratories.

A. ITVM is housed in Building 990, in the West Campus of Texas A&M, near the research farm area of the College of Veterinary Medicine. The laboratory equipment in use is modern and in a state of good repair, and includes a histopathology laboratory, and immunology and serology laboratories. ITVM is located on about 8 acres of land, with modern animal holding areas.

B. An arthropod tissue culture laboratory is operated in Room 304 of the Veterinary Medical Administration Building, College of Veterinary Medicine.



C. A satellite laboratory, utilized jointly with the U.S.D.A. and the Texas A&M Department of Entomology, is located near Falcon Heights, Texas, on a 30-acre peninsula owned by the U.S. Government. It is doubly fenced, with excellent barns and laboratories for rearing of ticks and for transmission studies of anaplasmosis and babesiosis. The Falcon Tick Research Facility is particularly well suited for investigating various methods of control of Boophilus ticks, and many different chemicals are being tested now. A new laboratory is in the final stages of construction on the site and should be completely operational by 15 August 1978.

## II. Personnel

Most of the scientific personnel, including the Director, are bilingual (English and Spanish). All have had extensive experience in animal disease research in Africa and Latin America. Recruitment of highly competent individuals with documented interests in international veterinary medicine has been no real problem but has been impeded by budgetary constraints. A great advantage enjoyed by ITVM is the large pool of consultants available to it from other departments in disciplines such as reproductive physiology, parasitology, entomology, animal science, nutrition, pathology, microbiology, marine biopathology, and public health.

## SUMMARY OF ACCOMPLISHMENTS

Summary of  
Accomplishments

An itemized list of every achievement by each faculty member over a period of five years would unnecessarily pad this report. Nevertheless it is necessary to list the major goals realized to illustrate the benefits derived from the 211d grant made to ITVM.

1. A well-stocked library was developed.

Over the course of years, this repository of information on tropical animal medicine has grown tremendously. Study sets on over 20 infirmities of animals in tropical environments have been prepared. These consist of color transparencies depicting gross features and microscopic lesions, microslides for histopathologic study, and appropriate syllabi for each set. Over 5,000 color slides of diseases are on file and over 15,000 scientific articles are available on a wide variety of diseases.

2. Two on-campus conferences on "Foreign Animal Diseases" were sponsored, featuring outstanding speakers from various parts of the U.S. One conference attracted several hundred veterinarians and veterinary students.

3. An arthropod tissue culture laboratory was established in Room 304 of the Veterinary Medical Administration Building. This laboratory, supported also by state funds, quickly established a capability for adapting cells of Boophilus microplus to laboratory cultivation. Currently ITVM has B. microplus, B. annulatus, and Rhipicephalus appendiculatus growing in culture. It is hoped that an effective antigen can be made against bovine

babesiosis and anaplasmosis by culturing the causative protozoan agents in these cell lines, with subsequent attenuation of them.

4. Over 100 articles and presentations on research activities at ITVM were produced by the scientific staff.

5. In conjunction with the Animal Science Department and the other Consortium members, a study was made of managerial, social, environmental, and disease constraints to efficient livestock production in Guyana. ITVM's share of this report is included in Appendix I.

6. A considerable number of graduates were trained at the Master of Science and Doctor of Philosophy levels, some solely under 211d sponsorship. A list of graduates is presented in Appendix II.

7. Consultantships were provided to Nicaragua, Costa Rica, Panama, Trinidad, Brazil, Peru, Ecuador, Australia, and the Dominican Republic.

8. Results of hemoprotozoal research done over a period of ten years at the Centro Internacional de Agricultura Tropical, Cali, Colombia, South America and at the laboratories of the Instituto Colombiano Agropecuario in Bogota, have been submitted in the form of a 10-year report to USAID. In one facet of the study, over 500 bovids were premunized on 12 ranches in the Cauca Valley with zero losses from anaplasmosis or babesiosis. In contrast, controls suffered high mortality from these diseases, survivors required frequent treatment, weighed far less (about 75 kg), and produced much less milk (about 33%) than those premunized. (For precise details of methodologies, statistical analyses, and results, see ITVM report of this study.)

9. International requests for assistance.

In the terminal stages of this grant, ITVM received numerous requests from Latin American countries for assistance in suppressing outbreaks of hemoprotozoal diseases and in designing long-range programs of animal health tailored to specific needs of the requesting country. Despite eager intents of both ITVM and requesting ministries of developing countries to affiliate and explore mechanisms to transfer the desired technology, a major frustrating impediment has been the lack of financial support to launch the needed programs in any of the soliciting countries.

10. Established liaison with foreign agencies.

ITVM has been enabled, through the 211d grant, to seek and maintain contact with a large number of foreign laboratories and agencies. Among these are the following:

- a. Centro Internacional de Agricultura Tropical, Cali, Colombia, S.A.
- b. Instituto Colombiano Agropecuario, Bogotá, Colombia, S.A.
- c. Colegio de Medicina Veterinaria, Universidad de Caldas, Manizales, Colombia
- d. Royal (Dick) School of Veterinary Studies, Center for Tropical Veterinary Medicine, University of Edinburg, Scotland
- e. Ministry of Agriculture, Guyana
- f. Ministry of Agriculture, Ecuador
- g. Ministry of Agriculture, El Salvador
- h. Ministry of Agriculture, Panama

- i. Commonwealth Scientific and Industrial Research Organization,  
Australia
- j. International Laboratory for Research on Animal Diseases,  
Nairobi, Kenya

ITEMIZED SUMMARY OF 211(d) GRANT UTILIZATION

by

INSTITUTE OF TROPICAL VETERINARY MEDICINE  
TEXAS A&M UNIVERSITY

ITEMIZED SUMMARY OF 211(d) GRANT  
UTILIZATION BY INSTITUTE OF  
TROPICAL VETERINARY MEDICINE,  
TEXAS A&M UNIVERSITY :

	Item Allocation, 29 June '72 - 31 Dec '77	Actual Expenditures 29 June '72 - 31 Dec '77
Salaries	\$131,500	\$126,328.75
Graduate Assistantships	55,000	41,387.40
Travel	40,000	23,321.14
Communications, library, etc.	1,000	788.65
Other (publications, printing, data processing supplies)	17,500	20,018.75
TOTAL	\$250,000	\$231,464.71
Returned to AID		18,535.29



## DETAILED REPORT

DETAILED REPORT

I. General Background and Purpose of the Grant

From its inception it has been the purpose of this Consortium and its members individually to develop and improve the level of knowledge and methodology which can be applied to increase the efficiency of livestock production in the tropics. Our participation in animal health has been greatly facilitated by our research contracts with AID involving the opportunity to have our graduate students work in Colombia, as well as in Guyana and Texas. Consequently, our professional staff and our graduate students have benefited much more from the 211(d) program than if Guyana had been our only opportunity for tropical disease experience.

The need for more efficient livestock production in the tropical world is very great. With the world human population rapidly exceeding its food supply, all types of food resources must be increased if massive starvation is to be avoided. Protein foods are in shortest supply, most costly to produce and animal proteins are especially essential for pregnant women and growing children. Further, if the world's potential for food production is to be developed, we cannot let that 65% of the world's land area go unused which is only capable of producing forages for ruminants. Likewise, the harvest of grain from cereal crops leaves some 40% of the nutrient in straw which can only be converted to food for man through livestock. The greater the food deficit the more important that animal production be efficient, and disease is a major handicap to efficiency. Not only does disease reduce the productivity of affected animals but the mere presence of serious contagious diseases in a country often prohibits the utilization of

more productive but less disease resistant breeds and also prevents the exportation of animals or their products to clean countries. As such, animal diseases often pose the major handicap to a nation's animal industry.

It is for these reasons that we consider the development of information and the training of personnel in the diagnosis, prevention and control of disease to be our mission. We try to integrate this information into the Consortium so that comprehensive plans and methods for optimal livestock production in the tropics can be developed and applied.

## II. Objectives of the Grant:

### 1. Objectives Restated

To improve staff and graduate student capability at Texas A&M University to design and conduct efficient disease prevention and control programs for ruminant livestock production in the tropics. This objective to be attained through the provision of training and experience for staff personnel. The training to be accomplished through staff involvement in academic education, research, and field application. Since efficient livestock production involves management, breeding, nutrition and economic considerations as well as disease control, this is a cooperative Consortium effort to develop all essential aspects of livestock production.

### 2. Review of Objectives

The area of responsibility within the 211(d) Consortium delegated to the ITVM is to develop a high level of competence in the diagnosis, prevention, and control of those livestock diseases of the tropics which most seriously handicap livestock production. Many of these diseases are most

severe in the least developed countries which have also done the least research work to develop effective means of control. It follows that for many of those diseases there is a great need for research, and a scarcity of information which is widely scattered through the world's literature. To assemble such information as is available required the collection of reprints from obscure foreign journals, the proceedings of international animal disease conferences and correspondence with other workers. It is also the purpose of the workshops in which we participate to update our information on specific diseases.

In view of the situation on the literature for exotic animal diseases it follows that an adequate training and research program aimed to push forward the application of pertinent knowledge must entail the development of an accessible library through the following steps:

- 1) Develop and keep current a library of relevant information on each major exotic animal disease;
- 2) Develop training aids which will include colored slide transparencies for projection of clinical cases, of gross and histopathology, pathogenic organisms, and parasites;
- 3) Collect pathologic specimens, consisting of gross tissues, histologic slides, blood smears and pathogenic organisms;
- 4) Conduct an active research program to develop a better knowledge of each disease;
- 5) Conduct a research program to develop and apply improved methods for diagnosis, treatment, and prevention of each disease;
- 6) Develop and conduct a training program to convey available

information to undergraduate professional students, graduate students, veterinarians and livestock producers.

#### GRADUATE STUDENT TRAINING

The ITVM professional staff is involved in the training of post D.V.M. U.S. and foreign graduate students in several ways.

All of our students seeking advance degrees who do their training at Texas A&M obtain their formal academic training in one or more of the departments of Veterinary Microbiology, Veterinary Pathology or Veterinary Parasitology in the College of Veterinary Medicine. Those who were supported by our AID programs did their research on problems which assisted in fulfillment of our AID mission and responsibilities either here in Texas, in Colombia, in Guyana, or in Africa.

During 1975-76, Drs. Thomas Craig, John Wyss, David Hopps, Sonny Reynolds and Tom Kyzar participated in our graduate training program with the first three as part-time 211(d) fellows.

Dr. Tom Craig did his academic work in Veterinary Parasitology and his research in Guyana, where he engaged in a survey of livestock diseases and collected large numbers of specimens which he brought back to Texas for several months of diagnosis and study. The Abstract from his dissertation accompanies this report as an Appendix and his dissertation is available in our library. Although Dr. Craig received his Ph.D. in December, 1975, he continued to work with the 211(d) Consortium where he helped to integrate his findings into the animal production models being prepared by Dr. T.C. Cartwright and Dr. T. Kelley White. The Consortium had a meeting in Guyana,

in March, 1976, to complete the model work for Guyana, and to report the results to the Guyanese Government. Dr. Craig has since become a full time faculty member for the Department of Veterinary Parasitology but he retains an active interest in Tropical Veterinary Medicine.

Dr. John Wyss, D.V.M., did his academic work here in Veterinary Microbiology. He also spent two years with ITVM in Colombia, where he worked part time on our program and part time on his own research project. His research efforts were concerned with adapting Babesia bigemina organisms to laboratory cultivation in mammalian-derived tissue with the hope that if these organisms could be grown in sufficient quantity in culture that they might prove valuable as a vaccine against babesiosis. His dissertation is entitled, "The In Vitro Cultivation of Babesia bigemina Utilizing Bovine Cells in Culture." The abstract from his dissertation is presented in the Appendix, and a copy of his dissertation is available in our library. Dr. Wyss received his Ph.D. degree in the spring of 1976, and found employment with the U.S. Department of Agriculture in Central America.

Dr. David Hopps, D.V.M., did his academic work in the department of Veterinary Parasitology followed by roughly two and one-half years in Colombia, where he worked three-fourths time on our research program and one-fourth time on his own research, until 1 July 1975, when he shifted to full time on his own research and to 211(d) support. Dr. Hopps returned to Texas A&M in January, 1976, where he completed his dissertation and received his Ph.D. degree in the spring of 1976. Dr. Hopps's research was on a comparative evaluation of available diagnostic tests for bovine babesiosis and anaplasmosis. An abstract of Dr. Hopps's work will be found in the Appendix to this report,

and a copy of his dissertation is in the ITVM library. Dr. Hopps accepted an appointment with a commercial drug firm where he is involved in the development of therapeutic drugs for the control of tropical diseases in food-producing livestock.

Dr. Sonny D. Reynolds, D.V.M., then a Major in the U.S. Army Veterinary Corps, was assigned here with the ITVM to obtain a Master of Science degree in tropical veterinary medicine. Dr. Reynolds did his academic work in Veterinary Microbiology and his research with the Institute of Tropical Veterinary Medicine here in Texas. He worked primarily with Dr. K.L. Kuttler on the "Evaluation of Methods of Premunition against Anaplasma marginale." He completed his research, wrote his thesis, obtained his degree and returned to an assignment for the U.S. Army Veterinary Corps. An abstract of his thesis is in the Appendix and a copy of his thesis is in our library.

Dr. Carl Tom Kyzar, D.V.M., Captain, U.S. Army Veterinary Corps, was assigned here to the ITVM to earn a Master's degree in Tropical Veterinary Medicine from August, 1973, to the fall of 1975. Dr. Kyzar did his academic work in Veterinary Microbiology and then spent one year with our team in Cali, Colombia, where he did research on "An Evaluation of the Card Test for the Diagnosis of Bovine Babesiosis." He returned to a military assignment before completing his thesis but subsequently completed it and received his Master of Science degree in the spring of 1976.

All five of these graduate students have done well in their work and have greatly enhanced their capability to help control livestock diseases in the tropics and so helped fulfill our objectives under the 211(d) Grant.

In addition to the above graduate students seeking advanced degrees, we had two veterinary science graduates from Tanzania, Mr. Gamaliel S. Tom

and Mr. Wilson J. Mpayo who received 3 months of training at ITVM in the spring of 1976. They also studied part time in Dairy Science since both men were involved in the care and management of dairy cattle in Tanzania. These men were sponsored by the Heifer Project International of Little Rock, Arkansas.

Our staff members in Colombia, Drs. R.A. Todorovic, Don Corrier and research assistant Ray Long, provided training in haemoprotozoal disease work for veterinarians from several Latin American countries. Dr. Todorovic was officially invited by the Dominican Republic at their expense and by Brazil, at CIAT expense, to interview prospective candidates for training in haemoprotozoal diseases by our team at CIAT in Colombia. He also discussed future cooperative projects in haemoparasitic diseases between CIAT - Texas A&M and Universidade Federal do Rio Grande do Sul, Brazil.

Additions of reprints, theses, dissertations, reference books and periodicals have been made to the ITVM library of information on exotic diseases which handicap livestock production.

The ITVM library of training aids has been improved through the addition of study sets of Kodachrome slides accompanied by a brochure of commentaries for each set. Study sets have been loaned and material for them exchanged with other investigators to increase our coverage. Please see Appendix I.

In 1976 the Texas Agricultural Experiment Station began to support ITVM. The initial sum awarded was \$21,000, and this amount was increased to over \$80,000 in 1977. Interest among Texas ranchers and cattlemen in ITVM activities was manifested by the contribution of 29 head of experimental cattle from the Callaghan Land and Pastoral Company of Encinal, Texas.



International requests for assistance in controlling hemoprotozoal cattle diseases greatly increased in the last year of the 211(d) grant. Solicitations for help were received from (and prompt response given to) Brazil, Panama, Costa Rica, Trinidad, Ecuador, El Salvador, Peru, and the Dominican Republic.

The 211(d) grant was the vehicle by which ITVM first obtained expertise in the culture of tick tissues. This knowledge led eventually to the establishment of an Arthropod Tissue Culture Laboratory, which has successfully propagated Boophilus microplus and B. annulatus in tissue culture. As soon as these cell lines and one of Rhipicephalus appendiculatus, donated by Dr. Mary Pudney of the London School of Hygiene and Tropical Medicine, are well established, it is intended to infect them with Babesia and Anaplasma organisms. From these efforts it is hoped that a far more effective antigen may be produced against these two cattle diseases, which cause so much damage in those tropical countries where the vectors abound.

The ITVM faculty and graduate students have been active in writing up their work. Over 100 papers, publications, theses and dissertations have been prepared. The references and abstracts of them are presented in Appendix VI.

#### Catalytic Effect of 211(d) Grant Support in Developing Institutional Capabilities:

The periodic invasion of Texas by Boophilus tick vectors of Texas fever (bovine babesiosis) from Mexico, and the constant threat which these ticks impose, has stimulated considerable interest among Texas livestock producers and concerned state officials in our hemoprotozoal research program.

Further, interest has resulted from the fact that U.S. cattle exports to Latin America have been a small percentage of their potential volume because of losses when susceptible American cattle are imported into the Babesia-infected countries of Latin America.: As a consequence of this interest, the State of Texas completed a cattle research facility for our use at Falcon Dam on a peninsula next to the Rio Grande River where, in collaboration with entomologists of Texas A&M and the USDA, we are now conducting research on both Texas fever and the tick vectors.

This provides us with a unique opportunity, in fact the only opportunity, to work on these important problems so close to home and to make this opportunity for such experience available to staff and students.

This is another example of how the availability of 211(d) support concurrent with other support from USAID was complementary to both programs.

## APPENDICES

## APPENDIX I

### Training Aids Prepared

The following study sets consisting of 35 mm Kodachrome colored slides which illustrate clinical, gross, and histologic pathology of tropical diseases have been prepared. For each set of colored slides there is a folder with a spiral binder containing commentaries for each slide. Also, for some diseases for which text book descriptions are not readily available we have also included a summary description of the disease.

East Coast Fever (ECF), 4 sets of 55 slides with commentaries  
Babesiosis of Deer, 4 sets of 23 slides with commentaries  
Theileria of Deer, 4 sets of 15 slides with commentaries  
Bluetongue of Deer, 4 sets of 39 slides with commentaries  
Bluetongue of Sheep, 4 sets of 39 slides with commentaries  
Foot & Mouth Disease in England, 4 sets of 26 slides with  
commentaries  
Disease Distribution Maps, 3 sets of 26 slides with commentaries  
Hemorrhagic Septicemia in Buffalo, 4 sets of 11 slides with  
commentaries  
Chagas' Disease, 3 sets of 84 slides with commentaries  
Chagas' Disease, 3 sets of 25 tissue sections with commentaries  
San Miguel Sealion Virus, 4 sets of 13 slides with commentaries  
Rinderpest (R), 4 sets of 40 slides with commentaries  
Rinderpest (R), 2 sets of 78 slides with commentaries  
~~African Swine Fever (ASF), 4 sets of 62 slides with commentaries~~  
Hog Cholera (HC), 4 sets of 54 slides with commentaries  
African Horsesickness (AHS), 4 sets of 40 slides with commentaries  
Epizootic Lymphangitis, 4 sets of 20 slides with commentaries  
Equine Piroplasmiasis, 4 sets of 51 slides with commentaries  
Canine Piroplasmiasis, 4 sets of 29 slides with commentaries

#### Prepared during 1975-76:

Anaplasmosis, 4 sets of 32 slides with commentaries  
Bovine Pleuropneumonia, 4 sets of 22 slides with commentaries  
and description of the disease  
Bovine Malignant Catarrh, 4 sets of 21 slides with commentaries  
and description of the disease  
Dermatophilosis (streptothricosis), 3 sets of 19 slides with  
commentaries  
Animal Parasites, 2 sets of 54 slides, with identification  
Insect Vectors, 2 sets of 45 slides, with identification

#### Histologic Slide Study Sets:

Anaplasmosis, 1 set of 10 slides with commentaries

Babesiosis, 1 set of 5 slides with commentaries  
Eperythrozoonosis, 1 set of 10 slides, with commentaries  
Theileriasis, 1 set of 7 slides with commentaries

Hemoprotozoal Identification Sets:

Hemoprotozoa (Jones), 1 set of 39 slides, with identifications  
Mixed Hemoprotozoa, 1 set with 6 slides, with identifications  
Hemoprotozoa (Neitz), 10 sets of 27 slides, with identifications

In addition, we have accumulated colored slides on the following diseases which will be used for study sets when additional slides of adequate coverage and quality are taken or otherwise obtained:

Bovine Streptothricosis	Maedi
Bovine Petechial Fever	Newcastle Disease
Bovine Mammilitis	Rift Valley Fever
Bovine Papillary Stomatitis	Sheep Pox
Contagious Ecthyma	Teschens Disease
Fowl Plague	Trypanosomiasis
Glanders	Tuberculosis
Heartwater	Vesicular Exanthema
Louping Illness	Vesicular Stomatitis

During 1976, Dr. Maurer gave to the Institute of Tropical Veterinary Medicine a personal collection of more than 3,000 additional histopathological tissue sections mounted and stained on glass slides, bringing the total to 6,140 slides he has given to the ITVM. A large percentage of these are on exotic animal diseases of the tropics. This constitutes a rare collection of specimens unavailable in other U.S. veterinary colleges. The current cost of preparing tissue sections is \$2.00 per slide, quite apart from the expense of collecting the tissues in several foreign countries. The slides are indexed and catalogued for convenient use.

It will be noted in the list of publications and in the title of papers delivered by our staff and visitors at the Workshops that we have comprehensive descriptions of many of the diseases for which we also have study sets so that we are well equipped with the essentials for the training of veterinarians on these diseases.

The Evaluation of the Colostral Immunity and the Immune  
Response to Bovine Babesiosis Using the Complement  
Fixation Test and the Indirect Fluorescent Antibody Test

(1976)

David Craig Hopps, B.V.Sc. - Candidate for Ph.D.  
Institute of Tropical Veterinary Medicine

and

Department of Veterinary Parasitology  
College of Veterinary Medicine  
Texas A&M University  
College Station, Texas 77843

The objectives of this research in Colombia were to establish two serological tests (indirect fluorescent antibody and indirect hemagglutination) for routine use in the laboratory, and to attempt to refine and preserve antigen for a card agglutination test for babesiosis. It was proposed to compare these three tests to the complement fixation test in terms of sensitivity, specificity, and reliability of diagnosis of infections due to B. argentina and B. bigemina.

The IFA test for both species of Babesia was established for routine use in Colombia and is now the standard test for babesiosis, together with the CF test in the ITVM laboratories. A card agglutination test for bovine babesiosis was attempted using B. argentina and B. bigemina, but the antigens prepared were all either non-reactive or not consistent in their reactions. The IHA test (microtiter) was performed using IBR virus antigen but Babesia antigen preparation or antigen sensitization of erythrocytes was not successful.

The CF test and IFA test were applied to sera collected from three experiments. Experiment 1 involved 6 cattle infected once with B. argentina and 6 cattle infected once with B. bigemina. The CF results from the B. argentina animals showed that CF titers were still positive at the end of one year, and there was only a transient low level heterologous titer to B. bigemina. IFA test results were of high titer and also persisted until the end of the year. A heterologous titer to B. argentina was present at low levels for the first 4 months.

All of the B. bigemina animals also remained carriers for the entire year. CF reactions for B. bigemina were of low titer and did not persist over 4 months. Titers to B. argentina persisted for over 7 months, even though this was the heterologous reaction. IFA reactions in the 6 B. bigemina cattle were of high titers to B. bigemina and lasted for 11 months.

Cross reactions to B. argentina were of low titer and persisted only 3 months.

In Experiment II six calves born in a highly endemic zone were exposed to natural infections without inoculation or treatment for hemoprotozoal disease for one year. They did not develop clinical disease even though they were continually exposed to B. argentina and B. bigemina. Their titers for B. argentina on the IFA test were variable, but were always positive after 6 weeks of age. Titers were considerably lower than in Experiment I, probably due to colostral immunity present at the time of the first infections.

The B. bigemina titers on the IFA test were also variable, and moderate levels were found except during a six-week period. CF titers to B. argentina were always positive during the year, but reactions to B. bigemina were usually on the borderline between positive and suspect.

In Experiment III calves born from naturally infected cows in an endemic area were allowed to ingest colostrum and were then kept free of infection for 6 months. The decay in colostral antibody titers was measured. B. bigemina titers were positive for about 1 month and B. argentina titers were positive for 2-1/2 months using the CF test. IFA titers were more similar for the two organisms and were positive until 3 months had elapsed.

The data presented show that the IFA test is a more sensitive and reliable indicator of the amount of antibodies present in infected animals than is the CF test. Colostral antibodies seem to be equally well determined by IFA or CF (B. argentina) test. The CF test for B. bigemina in these studies lacks sensitivity and reliability.

## ABSTRACT

The In Vitro Cultivation of Babesia bigemina  
Utilizing Bovine Cells in Culture.

(May 1976)

John Herbert Wyss, B.A., Texas Christian University,  
and D.V.M., Texas A&M University

Directed by: Dr. Stewart McConnell

Babesia bigemina in vitro cultivation experiments utilizing primary and continuous monolayer cultures were conducted. Experiments to infect normal non-infected cells by in vitro inoculation using fresh or stabilate B. bigemina-infected blood as inoculum were conducted with primary monolayer cultures of bovine spleen, lymph node, hemal node, and fetal kidney and continuous monolayer cultures of African Green Monkey kidney cells Vero. When fresh infected blood was used as inoculum the B. bigemina organisms dissociated from their host erythrocytes by day 2 and extracellular parasites were identifiable for up to 5 days on the surface of the cultured cells. When stabilate preparations were used as inoculums the majority of the parasites remained intraerythrocytic with few extracellular parasites being observed. Babesia bigemina-infected erythrocytes present in the inoculum were observed for up to 14 days on the surface of the cultured cells; however, the parasites were degenerative and pyknotic in appearance. No differences were observed between the various types of cultured cells or multiplication of organisms took place in the original cultures or subsequent subcultures.

Experiments with primary monolayer cultures derived from B. bigemina-infected calves were conducted with spleen, lymph node, hemal node and leucocyte cultures. Five days after culture seeding B. bigemina organisms could be found only in splenic monolayer cultures and could be identified in such cultures for 11 days post culture. The number of B. bigemina organisms decreased with time and there was no evidence that infection of cultured cells occurred or multiplication of the parasite took place. The subsequent 7 subcultures of the monolayer cultures did not demonstrate any evidence of being infected with B. bigemina and no subcultures of detached cells suspended in media could be established.

Babesia bigemina in vitro cultivation experiments utilizing erythrocyte maintenance suspension cultures were conducted. Experiments to infect normal non-infected erythrocytes maintained in suspension culture were conducted using fresh and stabilate infected blood preparations. In addition, B. bigemina-infected blood was also placed in maintenance cultures. Before the erythrocyte maintenance procedures were improved a similar situation existed as with monolayer cultures. When fresh infected blood was used as inoculum



or placed in maintenance culture the B. bigemina became extraerythrocytic within 24 hours and failed to infect other non-infected erythrocytes. When stabilate preparations were used infected ghost erythrocytes were observed up to 2 days. Morphologically the B. bigemina were degenerative. As the erythrocyte maintenance procedures improved infected erythrocytes were observed up to 4 days and infected erythrocytes held in maintenance culture 3 days were proven infective for a susceptible splenectomized calf.

## ABSTRACT

Evaluation of Methods of Premunition to  
Anaplasma marginale

(May 1975)

Sonny Delon Reynolds, B.S., Tennessee Technological University,  
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Chairman of Advisory Committee: Dr. K.L. Kuttler

Twenty-one yearling, crossbred, beef heifers were divided into 3 experimental groups and premunized by inoculating intravenously 2 ml of a  $10^{-2}$  dilution of an Anaplasma stabulate of Texas origin. A similar group of 4 heifers was maintained as non-infected controls.

Seven cattle in group I were vaccinated with "Anaplaz" 2 times, at a 4-week interval, prior to the premunizing infections. Nine cattle in group II were premunized and allowed to go untreated during the course of infection. Five cattle in group III were each treated with 11 mg/kg oxytetracycline intravenously when the Anaplasma parasitemia was about 4.6%.

Complement-fixation (CF) titers preceded the appearance of an Anaplasma parasitemia by up to a week. Clinical manifestations associated with Anaplasma parasitemia were mild in all groups and limited to rough haircoat, an unthrifty appearance and a slight loss of weight. The infection in all groups was characterized by lower packed cell volume (PCV), reduced red cell counts, low hemoglobin and increases in the mean corpuscular volume when compared to the controls; however, no significant group differences in these parameters were detected. Cattle of group I showed slightly longer incubation times and higher CF titers than cattle in groups II and III. The recovery rates for cattle in groups I, II and III showed no significant differences.

A challenge consisting of 5 ml whole, fresh blood from a splenectomized calf showing an 8% Anaplasma parasitemia and a 20% PCV was administered intravenously to all 25 experimental cattle after the premunizing infection had subsided. This challenge was calculated to represent over 100,000 times more infectious particles than the premunizing infection. Premunized animals were solidly immune to challenge, whereas the controls were severely affected.

REPORT OF THE USAID 211d BEEF  
CATTLE PRODUCTION CONSORTIUM,  
CONCERNING LIVESTOCK DISEASES  
IN GUYANA

This report consists of information gained through review of literature; personal communication; observation from 23 May to 1 September, 1974, in those areas of Guyana where cattle are raised; and subsequent laboratory findings.

Not all disease conditions of cattle are discussed. Only those caused by infectious agents or factors affecting large numbers of livestock are considered here. Fortunately, most of those infectious diseases which have decimated the livestock populations of other lands are not present in Guyana or other Western hemisphere countries. If this status is to be maintained, stringent laws affecting imports must be maintained.

### CATTLE DISEASES

#### Tuberculosis:

Inspection records of the Georgetown municipal abattoir were examined for the two and one-half years preceding this study in which 33,839 cattle were slaughtered at this premise and 1,105 (3.26%) were found with lesions suggestive of tuberculosis. As a result of this finding 1,639 cattle were tested by the caudal fold test and 46 reactors identified a prevalence of 2.9%. The cattle tested were selected mostly from animals producing milk for human consumption. These cattle were selected due to public health considerations and relative ease of handling as compared to beef cattle. Each animal had to be handled twice in order to be sensitized and to detect delayed hypersensitivity. Several clinical cases of tuberculosis were identified and appropriate action suggested. The results of tuberculosis testing in various areas of the country are indicated in Table I.

Due to the public health significance of such findings together with the general lack of pasteurization facilities, it is recommended that the Ministries of Health and Agriculture institute a plan of action and introduce suitable legislation towards the eventual eradication of bovine tuberculosis in Guyana. The first efforts should be directed to the public milk supply especially that supplied to various Governmental agencies, i. e., hospitals, schools, etc. The onus should be placed on the producer to provide adequate facilities for the testing of his animals. An accurate method of identifying individual animals must be provided.

The caudal fold test should be quite adequate for conditions encountered in Guyana, but if problems arise in certain areas due to nonvisible lesions reactors, other tests may be considered.

TABLE I TUBERCULIN REACTORS

	<u>No. tested</u>	<u>Reactors</u>	<u>% Reactors</u>
Matthews' Ridge *	83	0	0
Essequibo	179	0	0
Mazaruni, Bartica	83	5	6.0
West Demerara	273	0	0
East Bank Demerara	164	8	4.9
Georgetown	263	1	0.4
East Coast Demerara	95	8	7.7
West Berbice	48	8	16.2
East Berbice	314	16	5.1
Ebini	97	0	0
Rupununi	32	0	0
TOTAL	1,639	46	2.9

\* In this table and all others in the report the areas of the country are as follows and are indicated in Figure I.

Matthews' Ridge: Matthews' Ridge and Kaituma.

Essequibo: Essequibo coast from Suddie to Charity and the islands of Leguan and Wakenaam.

Mazaruni, Bartica: Mazaruni Prison and Bartica.

West Demerara: West Demerara and East Essequibo coast from Vreed-en-Hooft to Parika and the west bank of the Demerara River from Vreed-en-Hoop to Wales.

East Bank, Demerara: The east bank of the Demerara River from Timehri to Georgetown.

Georgetown: Georgetown and environs including Bel Air Dairy.

East Coast Demerara: From Georgetown to the Abrary River.

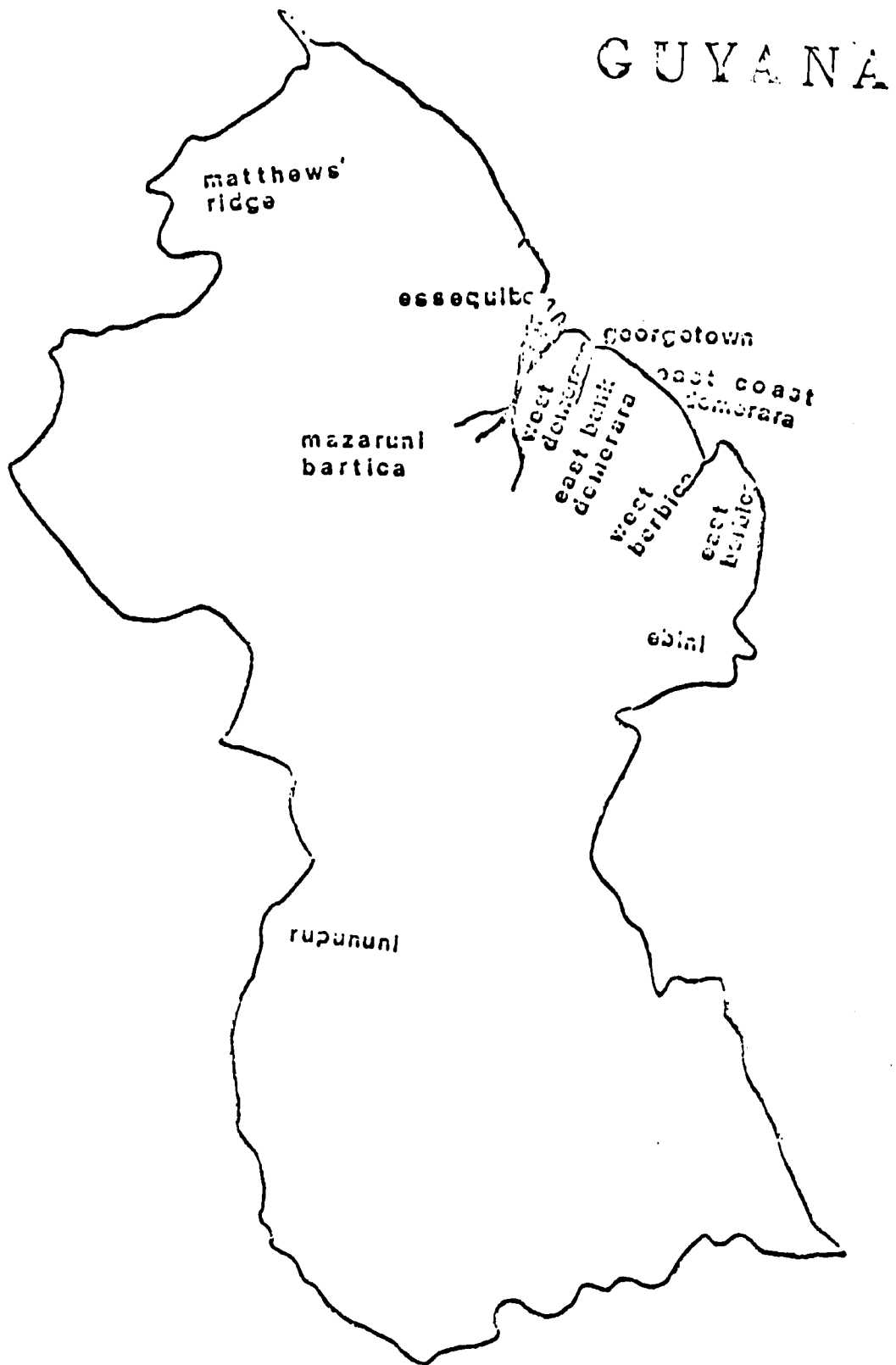
West Berbice: From the Abary River to the Berbice River including Kabawa.

East Berbice: From New Amsterdam to Sisters on the east bank of the Berbice River and New Amsterdam to Crabwood Creek along the coast and Black Bush Polder.

Ebini: The Government experiment station at Ebini.

Rupununi: The villages and ranches of Orinduik, Karasabai, Anni, Lethem, Pirara, Marakanata, Napi, Yupukarri, Manari, St. Ignatius, Manari outstation, Dadanawa and Aishalton.

FIGURE I



### Brucellosis:

A total of 368 sera were tested using the brucellosis card test. No positive sera were identified. This agrees with data collected in 1972 and 1973. Earlier reports indicating a high prevalence of brucellosis probably indicate laboratory error as the present serological study and clinical evidence does not indicate disease. It would appear that this disease is not now a problem in Guyana, and vigorous surveillance of imported livestock should prevent its introduction.

### Leptospirosis:

A serological survey done in 1973 indicates a prevalence of 38% of the cattle tested in Guyana had leptospira antibodies. Those sero types associated with cattle disease found in Guyana are listed (not all positive sera were of bovine origin): L. hardjo, L. sejroe, L. canicola, L. icterohaemorrhagiae, L. hebdomadis, L. pomona and L. grippotyphosa. At first glance it would seem that Leptospira are important pathogens in Guyana, especially in view of the high rainfall and warm climate.

No evidence of leptospirosis was encountered either as an acute infection of young calves or a chronic abortion problem. The organism is very susceptible to pH levels lower than 6, and transmission via the acidic ground waters of Guyana is probably negligible.

If, however, in a local area, clinical signs of disease, associated with a rising titre to Leptospira occurs, vaccination with appropriate bacterin may be used. It is unlikely that the use of bacterins against Leptospira as a prophylactic measure at this time would be economically justified.

### Anaplasmosis:

A total of 788 sera from native cattle were tested using the Anaplasma marginale card test. There were 668 (84.7%) serologically positive cattle. A considerable percentage of the non-positive cattle were less than 6 months of age (Table II). Eighty four imported cattle at Mon Repos were similarly tested and 55 (65.5%) were serologically positive. A large percentage of those not found to be positive were from one group imported about two and one-half months prior to testing (Table III). Sera from 168 native and imported cattle were tested, at the Texas A&M University Institute of Tropical Veterinary Medicine (ITVM) laboratory with the Anaplasma complement fixation (CF) test. The results compared with those obtained by card test are indicated in Table IV. An agreement of 85.1% was noted between tests.

The serological prevalence of anaplasmosis in various breeds of cattle in Guyana are indicated in Table V. Zebu and Zebu-cross cattle are defined as those with recognizable Bos indicus breeding; European and European-cross which are those exhibiting breed characteristics of any readily recognizable breed (Hereford, Holstein-Friesian, Charolais); and Creole which are cattle of unknown ancestry without sufficient breed

TABLE II  
HEMOPARASITE SEROLOGY UTILIZING THE ANAPLASMA RAPID  
CARD TEST AND BABESIA COMPLEMENT FIXATION TESTS

	<u>A. marginale</u>		<u>B. bigemina</u>		<u>B. argentina</u>	
	>6 mos.	≤6 mos.	>6 mos.	≤6 mos.	>6 mos.	≤6 mos.
Matthews Ridge	*78-84 92.9%	15-16 93.8%	9-84 10.7%	2-16 12.5%	2-84 2.4%	1-16 6.3%
Mazaruni, Bartica	12-12 100%	4-6 66.7%	1-11 9.0%	5-5 100%	0-12 0%	1-5 20.0%
Essequibo	31-38 81.6%	6-10 60.0%	17-37 45.9%	6-10 60.0%	10-37 27.0%	3-10 30.0%
West Demerara	35-53 66.0%	15-22 68.2%	9-53 17.0%	2-22 9.1%	2-53 3.8%	1-22 4.5%
East Bank Demerara	23-25 92.0%	5-13 38.5%	7-24 29.2%	3-14 21.4%	9-25 36.0%	1-13 7.7%
Georgetown	37-45 82.2%	11-12 91.7%	10-44 22.7%	2-12 15.7%	1-44 2.3%	2-12 16.7%
East coast Demerara	59-66 89.4%	22-30 73.3%	17-65 26.2%	15-29 51.7%	5-66 7.6%	1-30 3.3%
West Berbice	23-30 76.7%	4-5 80.0%	14-20 70.0%	4-5 80.0%	7-20 35.0%	3-5 60.0%
East Berbice	41-46 89.1%	6-12 50.0%	22-45 48.9%	6-12 50.0%	4-45 8.9%	0-12 0%
Ebini	90-91 98.9%	6-9 66.7%	27-91 29.7%	6-9 66.7%	9-91 9.9%	6-9 66.7%
Rupununi	118-124 55.2%	27-39 69.2%	35-121 28.9%	18-39 46.2%	14-121 11.6%	5-38 13.2%
	547-614 89.1%	121-174 69.5%	168-595 28.2%	69-173 39.9%	63-598 10.5%	24-172 14.0%

\* Number positive - number tested  
Percent positive

TABLE III

## Serology for Hemoparasitic Organisms at Mon Repos, Guyana

Groups	Imported heifers *					
	<u>A. marginale</u>		<u>B. bigemina</u>		<u>B. argentina</u>	
1	8-8 **	100.0 ***	5-8 **	62.5 ***	3-7 **	42.9 ***
2	10-11	90.9	10-11	90.9	5-11	45.5
3	6-6	100.0	6-6	100.0	3-6	50.0
4	5-6	83.3	5-6	83.3	2-6	33.3
5	11-13	84.6	8-13	61.5	7-13	53.8
6	11-13	84.6	11-13	84.6	5-13	38.5
7	0-21	0	14-22	63.6	13-22	59.1
8	3-17	16.7	16-17	94.4	15-17	83.3
9	16-27	59.3	24-27	88.9	25-25	100.0
Total	70-122	57.4	99-123	80.5	75-120	62.5
Native heifers ****	7-8	87.5	1-8	12.5	1-8	12.5

\* Heifers imported into Guyana from Boophilus-free zones at 4-6 months of age, present in country from 6 weeks to 1 year at time of collection. Group 1 in Guyana the longest period of time; group 9 shortest. Heifers imported at 4 to 8 week intervals.

\*\* Number serologically positive - number tested

\*\*\* Percentage serologically positive

\*\*\*\* Selected native heifers raised with imported heifers at Mon Repos associated with different groups of approximately equal size and condition.

TABLE IV

## Comparison of the Anaplasma Complement Fixation (CF) Test and Card Test Test (CT) Results Using Sera Collected in Guyana

	<u>CT+</u>	<u>CT-</u>	<u>% Agreement</u>
CF+	102	8	92.7%
CF-	17	41	70.7%
% Agreement	85.7%	83.7%	



characteristics to be placed elsewhere.

TABLE V

A Comparison of Cattle Breeds in the Prevalence of Hemoparasite Positive Sera in Guyana

	<u>A. marginale</u>	<u>B. bigemina</u>	<u>B. argentina</u>
Zebu and Zebu X	162-186 87.1%	45-181 24.9%	19-163 11.7%
European and European X	250-305 82.0%	107-299 35.8%	40-257 15.6%
Creole	254-295 86.1%	85-290 29.3%	28-263 10.6%

This high prevalence of infection within the country practically ensures that imported cattle will come into contact with the organisms during their first year in the country (Table VI). The possible use of a killed A. marginale vaccine prior to export, or supervised premunition on arrival, may help relieve the serious stress placed on the animals during the acute phase of the disease.

#### Babesiosis:

Both Babesia argentina and Babesia bigemina were identified in blood films collected in Guyana. Complement fixation tests were run on sera collected from various regions in Guyana. The criteria for a positive serum was one that demonstrated 3 or 4+ (less than 50% hemolysis) intact sheep erythrocytes in a test system using a 1:5 serum dilution screen test. Of 768 native cattle tested, 237 (30.9%) were serologically positive for B. bigemina and 87 of 770 (11.3%) were positive for B. argentina (Table II). Cattle recently imported into Guyana were similarly tested with 99 of 123 (80.5%) positive for B. bigemina and 75 of 120 (62.5%) positive for B. argentina (Table III).

Boophilus ticks are the only known vector of bovine Babesia in the Western hemisphere. Several studies done elsewhere indicate a resistance by Zebu cattle to Boophilus ticks and a lower prevalence of Babesia due to lower challenge and a natural resistance to B. argentina by Bos indicus cattle. Table V indicates the prevalence of serologically positive cattle in various breed types with the Zebu cattle having a lower prevalence of antibodies than European cattle. Serological testing indicates only the presence or absence of antibody and give no indication of severity of disease an animal might have had or may experience. Perhaps the criteria of 3 or 4+ as being positive was too high to get a true picture of the prevalence of babesiosis as sera of many of the cattle considered negative had the ability to fix some complement. This ability to fix complement may have been due to small amounts of specific antibody or

TABLE VI

Serological Changes Incurred by a Group of Heifers Imported Into Guyana

Calf No.	* <u>A. marginale</u>				<u>B. bigemina</u>				<u>B. argentina</u>				PCV <sup>1</sup>			
	1	25	35	51	1	25	35	51	1	25	35	51	1	25	35	51
6143	-	-	-	+	-	-	+	+	-	-	A	+	35	31	22	25
6281	-	-	-	-	-	-	+	+	-	+	A	+	34	33	21	34
6514	2	-	-	-	A	-	-	+	A	-	-	+	30	28	29	22
6520	-	-	-	-	-	-	-	-	-	-	-	-	35	19	-	-
6581	-	-	-	-	-	-	+	-	-	+	+	+	31	21	22	16
6598	3	-	-	-	-	-	+	+	-	-	+	+	38	25	27	28
6694	-	-	-	-	-	+	-	-	A	-	-	-	33	22	-	-
6878	-	-	-	+	-	+	-	+	-	+	-	+	30	28	15	26
6886	-	-	-	-	-	-	-	+	-	-	-	+	34	31	21	36
6896	-	-	-	+	-	+	A	+	A	+	A	+	28	19	26	33
6906	-	-	-	+	-	+	+	+	-	+	-	+	40	43	30	26
6912	-	-	-	+	-	-	+	+	-	-	-	+	47	46	34	35
6931	-	-	N	+	-	+	N	+	-	+	N	+	35	19	N	29
6971	-	-	-	+	-	-	A	+	-	-	A	A	35	25	26	23
6985	-	-	N	+	-	+	N	+	-	+	N	+	31	25	N	25
7040	-	-	-	+	-	-	-	+	-	-	-	+	32	25	23	27
7050	-	-	-	+	-	+	+	+	-	+	-	+	32	10	25	29
7062	-	-	-	+	-	-	+	+	-	-	+	+	31	15	21	24
7096	-	-	-	-	-	-	+	+	-	+	+	+	42	19	25	23
7144	-	-	-	+	-	-	+	+	-	-	+	+	39	35	26	24
7153	-	-	-	+	-	-	+	+	-	-	+	+	39	13	22	29
7168	-	-	-	+	-	+	+	+	-	-	-	+	34	37	29	29
7187	-	-	-	+	-	-	-	+	-	-	-	+	38	31	26	28
7188	-	-	-	+	-	+	+	+	-	A	-	A	35	30	37	29
7192	-	-	-	-	-	-	+	+	-	-	A	+	35	31	24	27
7209	-	-	-	-	-	-	+	+	-	-	-	+	39	28	25	24
7211	-	-	-	-	-	+	+	+	-	A	+	+	44	33	27	29
7231	-	-	-	-	-	-	+	+	-	-	-	+	34	28	25	30
**	0	0	0	16	0	10	17	25	0	9	7	24	35.4	27.7	25.3	27.3
	28	28	26	26	27	28	24	26	25	26	19	24				
	0	0	0	61.5	0	35.7	70.8	96.2	0	34.6	36.8	100				

\* days after arrival in Guyana

\*\* number positive/number tested over percentage positive

1 PCV packed erythrocyte volume

2 calf died with B. argentina parasitemia3 calf died with B. bigemina parasitemia

A anticomplementary seru

N not available

to non-specific erythrocytic antibody against the crude antigen utilized in the complement fixation test.

The susceptibility of imported cattle to Babesia infections are demonstrated in Table VI. As can be seen from Table VI, the calves first demonstrated B. argentina and B. bigemina antibody by day 25 and A. marginale by day 51. Despite timely treatment, two calves of the original test group died with signs of babesiosis which indicated the need for extreme caution when importing cattle, especially from Babesia-free areas. The use of prophylactic drug treatment or induced premunition coupled with appropriate drug therapy is indicated especially when large numbers of cattle are imported.

#### Trypanosomiasis:

The examination of 1060 blood films from both native and imported cattle revealed four animals with a parasitemia of Trypanosoma vivax. In addition, 657 wet mounts were examined in an effort to detect trypanosomes; no trypanosomes were seen in wet mounts. The serological prevalence is unknown as is the economic importance of this organism.

#### Eperythrozooniasis:

One of 1060 blood films examined contained Eperythrozoon wenyoni and two contained E. teganoides. These calves were anemic and concurrently infected with Babesia bigemina. It is likely the Eperythrozoon parasitemia was stimulated by the stress incurred by the Babesia infection.

#### Helminth Parasites:

In an effort to determine which helminths are present in the country and give support to the field veterinarian as far as treatment and control programs are concerned, gastro-intestinal tracts from 21 cattle slaughtered at the Georgetown abattoir and 9 from the Lethem abattoir were examined grossly, washed, and an aliquote of gastro-intestinal contents examined with a dissecting microscope. The liver, larynx, heart, diaphragm, skeletal muscle, nuchal ligament and body cavities were examined grossly. One hundred fifty fecal flotations were examined. Feces were collected from young calves and from cattle with clinical signs of gastro-intestinal helminthosis.

The following helminths parasitizing cattle in Guyana were identified: Cotylophoron sp., Ostertagia sp., Trichostrongylus axei, Haemonchus contortus, Cooperia punctata, Bunostomum phlebotomum, Strongyloides papillosus, Toxocara (Neoscaris) vitulorum, Capillaria bovis, Oesophagostomum radiatum, Moniezia sp., Trichuris discolor, Dictyocaulus viviparus, Mammaomonogamus (Syngamus) laryngeus, Onchocerca linealis, Artionema (Setaria) labiatopapillosa and lesions of Stephanofilaria stilesi.

Comparisons of the helminthic fauna of the gastro-intestinal tracts of cattle from coastal areas and the Rupunani are given in Table VII. The cattle slaughtered at Lethem were older cattle killed at the end

of the rainy season, whereas in Georgetown, cattle from one year to aged were slaughtered during the rainy season. No history was available as to anthelmintic treatment of these cattle. Comparisons of numbers of worms obtained would not be significant. It is likely that examination of younger cattle (<6 months of age) or at different seasons would result in relatively different faunas. Parasite profiles for the rainy season at Georgetown and Lethem are indicated in Figure II.

TABLE VII  
Gastro-intestinal Helminths from Two Environmentally Dissimilar Areas of Guyana

	Georgetown % <sup>1</sup>	(Coastal) mean <sup>2</sup>	Lethem % <sup>1</sup>	(Rupununi-Savannah) mean <sup>2</sup>
<u>Haemonchus</u>	85.7	276	100.0	798
<u>Trichostrongylus</u>	76.2	114	100.0	259
<u>Ostertagia</u>	76.2	151	11.4**	20
<u>Bunostomum</u>	19.0	48	-----	---
<u>Cooperia</u>	81.0	1932	44.4	255
<u>Capillaria</u>	4.8	10	11.1	10
<u>Oesophagostomum*</u>	57.1	48	11.1	20
<u>Trichuris</u>	9.5	15	22.2	40

<sup>1</sup> Percent of cattle from which helminths were recovered

<sup>2</sup> Mean number of helminths recovered from parasitized cattle

\* Gross intestinal lesions of larval Oesophagostomum radiatum were identified in 19 of 21 Georgetown cattle and 9 of 9 from Lethem. Only adults are recorded in this table.

\*\* Only L<sub>4</sub> Ostertagia recovered at Lethem

Table VIII indicates the prevalence of Mammomonogamus laryngeus and Onchocerca linealis in different geographic regions of Guyana.

TABLE VIII

	<u>Mammomonogamus</u>		<u>Onchocerca</u>	
Georgetown	17/53*	32.1%	28/52	54.9%
Ebini	0/1	0	0/1	0
Lethem	0/13	0	22/33	66.7%

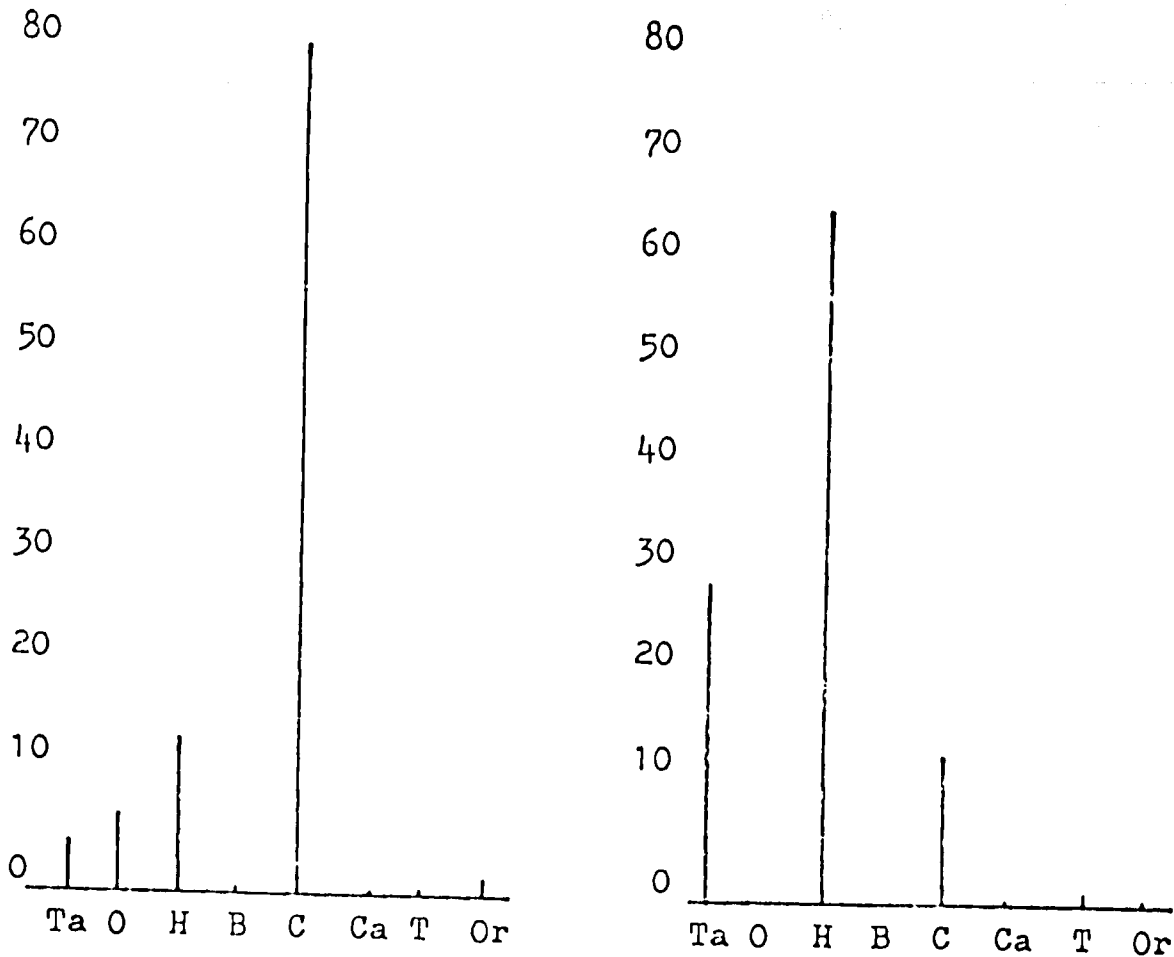
\* Number positive/number examined, % positive

FIGURE II

Parasite Profiles of Cattle in Different Environmental Areas of Guyana. Percentages of parasite genera based on total number of adult trichostrongyloid nematodes recovered.

Georgetown

Lethem



Ta= Trichostrongylus; O= Ostertagia; H= Haemonchus;

B= Bunostomum; C= Cooperia; Ca= Capillaria; T= Trichuris

Or= Oesophagostomum

Lesions of Stephanofilaria stilesi were observed only at Ebini. At the time of observation the intermediate host Haematobia irritans was present at Ebini in tremendous numbers, not noted in other parts of the country.

The most interesting observation was the failure to find evidence of infection with, or confirmed reference to, Fasciola sp., or Cysticercus bovis. The methods of meat inspection as generally practiced in Guyana might very well allow individual infections with these parasites to go unnoticed, but, if present, they would eventually be identified.

One of the possible reasons for the lack of Cysticercus bovis infections in Guyana may be sociological as many of the cattle owners and herdsmen do not eat beef. However, this does not apply to the Rupununi. When cysticercosis is first identified, efforts should be made by the Ministries of Agriculture and Health to trace the human source of Taenia saginata and cattle possibly exposed should be slaughtered under rigid inspection.

Because fascioliasis and schistosomiasis are unknown in Guyana, the Ministries of Health and Agriculture, possibly in conjunction with the University of Guyana, should undertake a survey of the snail population in the country with particular attention to pH, salinity and water temperatures where the snails are gathered. If snails suitable to be vectors of these conditions are found then vigorous examination of imported livestock and examination of persons from endemic areas should be instituted.

#### External Parasites:

Boophilus microplus ticks were found in nearly all parts of the country. No attempts were made to compare populations in the various regions, due to difficulties in assessing tick numbers under field conditions. However, it was noted that the numbers of ticks parasitizing cattle was the greatest on the Essequibo coast, especially at the Essequibo Boys' School. The number of ticks found on some of the cows was so great as to give a pebbled appearance to the skin. These cattle were suffering from severe alopecia and any resistance they may have established was completely overwhelmed. It is suggested that the ticks from this area be examined for ixocide resistance.

Boophilus microplus was also found on horses and water buffalo, but cannot be considered an important parasite of these species.

The cattle from Aishalon, Rupununi, were apparently free from Boophilus ticks. No ticks were found on careful examination of sixteen head of cattle, and the vaqueros stated that cattle did not have ticks at Aishalon. However, 4 head were serologically positive to at least one species of Babesia, which is as far as is known transmitted only by Boophilus ticks or by blood passage. Perhaps further investigation would reveal small numbers of ticks, possibly present only during certain seasons. If indeed only small numbers of ticks or no ticks are found in the area, the reason for this should be ascertained.

Amblyomma triste was collected from a cow at Ebini; this is the first report of this tick species in Guyana. It is unlikely that this tick is an important cattle parasite. Several A. cajennense were found in the vicinity of corrals in the Rupununi, and it is likely that they occasionally parasitize cattle but it is not considered to be an important cattle parasite at this time.

The tail louse Haematopinus quadripertusus was seen on cattle in coastal regions; most were seen on poorly managed farms.

Flying insects, or their larvae, parasitizing cattle in Guyana include: Haematobia (Siphona) irritans, Cochliomyia hominivorax, Dermatobia hominis, Simulium haematopotum and several genera of mosquitoes. The first three species were found in greatest numbers at Ebini, and S. haematopotum only in the Rupununi. Other flying insects are undoubtedly parasitizing Guyanese cattle, but specimens were not collected.

#### Foot-and-Mouth Disease:

Periodic outbreaks of Foot-and-Mouth Disease have occurred in the Rupununi Savannah. The economic disruptions that such a disease causes are far greater than the actual losses of production. Because of the ease with which it is possible to move livestock from Brazil, strict surveillance and a good education program to inform the local population about the dangers of moving livestock are necessary. Attempts to keep Guyana free of Foot-and-Mouth Disease will require the utmost cooperation on the part of the Brazilian authorities. A buffer zone vaccination program along the Brazilian border using killed vaccine will aid in prevention of the spread of the disease to susceptible cattle in other parts of the country.

Foot-and-Mouth Disease-free zones could be set up in the country in areas where the disease has never been reported and beef from the Rupununi is not consumed.

#### Rabies:

Rabies in cattle has been reported from the Rupununi, upper Berbice and Essequibo islands. Vaccination programs and vampire bat Desmodis rotundis control will help to control the disease in cattle.

Care must be taken not to diagnose all central nervous system disease as being rabies. Accurate diagnosis should be determined in all outbreaks.

#### Mineral Deficiencies:

Previous studies indicate the following minerals to be deficient in certain areas of Guyana: Phosphorus, cobalt, copper and zinc.

Sera from 429 cattle were examined by standard tests\* to determine

\* Hycel Test Kits, Hycel Inc. Houston, Texas

calcium and phosphorus levels. Results are indicated in Table IX. The results indicate that the serum calcium and phosphorus levels in general fall within the accepted normal range, however, phosphorus levels at Matthew's Ridge are less than the generally accepted 4 mg/dl. The generally high phosphorus levels in the Rupununi are surprising in view of past findings.

The technical problems were encountered with sera from certain areas. Hemolysis may have caused an abnormally high spectrophotometer reading. This was not considered to be a problem with many samples, and samples obviously hemolyzed were not used for serum chemistry.

Mineral supplements are recommended for all areas of Guyana with local needs considered as to the contents of the supplements.

#### Others:

Reports mention outbreaks of anthrax and blackleg but they do not seem to be widely present now, possibly due in part to the low pH of the soils within the country.

I have encountered what appears to be a clostridial infection in calves whose post mortem findings include subcutaneous edema, gaseous inflation of liver and kidney, and pulmonary emphysema, edema and rapid autolysis. Diagnostic capabilities for anaerobic organisms are essential for accurate diagnosis and recommendations.

Liver cirrhosis is seen occasionally in the abattoirs as are cattle showing lesions of photo sensitivity. The plant, or plants, suspected of causing this toxicity should be fed to experimental animals and results noted.

Specimens for histopathology were examined at Texas A&M University and helped to confirm diagnoses of hepatic damage and possible clostridial infections. Indications of chronic infectious disease were encountered, indicating possible hemoparasitic infection.

A condition known as "water itch" in calves is often seen on the coast during the rainy season. Unsuccessful attempts were made to isolate pathogenic fungi. The etiology of this condition should be investigated.

Clinical diagnoses of dermatophilosis were made. The lesions were most commonly found on the trunk and neck and could be associated with tick infestation. It is possible that Dermatophilus congolensis is the etiologic agent of "water itch"

The foremost 'disease' of cattle in Guyana is one of malnutrition. The practice of penning animals without access to forage at night and of milking beef cows during the first few months of a calf's life are not ones



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SERUM CHEMISTRY

>8 mo.

≤8 mo.

AREA	No.	>8 mo.		≤8 mo.		
		Ca Meq/L	PO4 mg/dl	No.	Ca Meq/L	PO4 mg/dl
Matthew' s Ridge	28	5.02 <sub>±</sub> 0.39	3.74 <sub>±</sub> 0.64	5	4.62 <sub>±</sub> 0.39	4.96 <sub>±</sub> 1.27
Mazaruni, Bartica	8	4.53 <sub>±</sub> 0.56	6.63 <sub>±</sub> 1.7	5	4.46 <sub>±</sub> 0.07	6.72 <sub>±</sub> 0.59
Essequibo	19	4.44 <sub>±</sub> 0.48	6.11 <sub>±</sub> 1.2	5	4.74 <sub>±</sub> 0.84	7.53 <sub>±</sub> 0.62
West Demerara	25	5.13 <sub>±</sub> 0.52	4.08 <sub>±</sub> 0.54	13	5.31 <sub>±</sub> 0.54	4.86 <sub>±</sub> 0.54
East bank Demerara	9	4.66 <sub>±</sub> 0.5	5.55 <sub>±</sub> 2.05	9	5.12 <sub>±</sub> 0.75	7.07 <sub>±</sub> 1.45
Georgetown	20	4.88 <sub>±</sub> 0.46	4.34 <sub>±</sub> 1.56	11	4.79 <sub>±</sub> 0.55	6.59 <sub>±</sub> 2.36
East coast Demerara	29	4.97 <sub>±</sub> 0.57	4.78 <sub>±</sub> 1.62	18	5.24 <sub>±</sub> 0.64	6.81 <sub>±</sub> 2.61
West Berbice	14	4.33 <sub>±</sub> 0.67	5.72 <sub>±</sub> 1.72	3	5.27 <sub>±</sub> 0.49	7.78 <sub>±</sub> 1.6
East Berbice	22	4.16 <sub>±</sub> 0.48	6.98 <sub>±</sub> 1.83	5	4.74 <sub>±</sub> 0.58	7.63 <sub>±</sub> 1.78
Ebini	22	4.28 <sub>±</sub> 0.56	6.21 <sub>±</sub> 1.36	10	4.51 <sub>±</sub> 0.49	6.85 <sub>±</sub> 0.99
Rupununi	60	5.04 <sub>±</sub> 0.55	6.21 <sub>±</sub> 1.68	18	5.38 <sub>±</sub> 0.55	8.41 <sub>±</sub> 1.24
	256	4.77 <sub>±</sub> 0.6	5.45 <sub>±</sub> 1.79	102	5.08 <sub>±</sub> 0.28	6.86 <sub>±</sub> 1.92
Imports	24	5.04 <sub>±</sub> 0.39	4.76 <sub>±</sub> 0.51	47	4.82 <sub>±</sub> 0.38	7.66 <sub>±</sub> 1.6

which allow the young animals to reach their full potential prior to weaning.

These malnourished cattle are more susceptible to the inroads of parasitisms or infectious disease as well as being inefficient converters of roughage into meat.

## SHEEP AND GOAT DISEASES

Not much work has been done with the diseases of sheep and goats which is rather surprising, considering the esteem in which mutton is held in Guyana. The purpose of these investigations was to look at cattle diseases; however, in the course of work, sheep and goats were examined.

### Internal Parasites:

The younger sheep were in generally poor condition throughout the country, with the exception of the areas of East Berbice and Karasabai in the Rupununi. The older animals were in better condition. An important consideration in sheep and goats is that of internal parasitism. The following helminths were found: Paramphistomum sp., Haemonchus contortus, Ostertagia sp., Trichostrongylus axei, Bunostomum trigonocephalum, Cooperia curticei, Trichostrongylus colubriformis, Moniezia sp., and Oesophagostomum columbianum. Management practices, such as a definite breeding season, pasture rotation and strategic drenching of ewes at the time of parturition coupled with vigorous, effective anthelmintic treatment of lambs and kids are necessary to keep the parasite numbers in control.

### Mineral Deficiencies:

Mineral deficiencies encountered in cattle are likely to be present also in sheep and they may in fact be more sensitive to trace mineral deficiencies. Trace mineral deficiencies, especially Cobalt and Selenium, should be investigated. Serum calcium and phosphorus determinations were run on 9 sheep. Serum calcium levels were  $5.86 \pm .53$  Meq/L and phosphorus  $6.26 \pm 1.05$  mg/dl within the normal range.

### Clostridial Infections:

Diseases caused by Clostridium spp., are a problem wherever sheep are raised. Gross lesions and histopathology indicate that Guyana is not an exception. Adequate diagnostic facilities are needed to determine which specific clostridial diseases are present in the country.

## HORSE DISEASES

The horse has a definite role in the cattle industry of Guyana and death or incapacity of horses can cause serious disruptions to the industry. No post mortem examinations on horses or donkeys were performed during this investigation, but available information indicates that the internal parasite problem in Guyana is similar to that of other countries with a similar climate. A regular worming program should be carried out.

### External Parasites:

Anocenter nitens was found on horses living between the Demerara and Berbice Rivers, on the coast and in the Rupununi. Regular treatment of the ears of horses infested with this tick is recommended as tick worry, secondary bacterial, fungal infections or myiasis can occur as a result of heavy infections. Anocenter may be the vector of Babesia equi in Guyana. Boophilus microplus ticks were found on horses at Ebini, but it is not thought this tick is an important parasite of horses in Guyana.

### Trypanosomiasis:

Wet blood mounts and stained blood films were examined from 47 horses. No trypanosomes were observed. However, well documented evidence indicates that Trypanosoma evansi infections have caused considerable death losses in the Rupununi district and it is likely that outbreaks may occur in the future. Prompt diagnosis and treatment will be necessary to control the disease.

### Babesiosis:

Examination of 47 stained blood films failed to disclose evidence of Babesia organisms. However, serological testing, at the USDA Agricultural Research Center, revealed 30 of 45 sera had CF titers of 1:5 or higher to B. equi but all sera were negative for B. caballi. Data on serologic status and packed erythrocyte volumes (PCV) are given in Table X.

### Rabies:

Bat transmitted rabies has been a recurring problem especially in the Rupununi. This problem should be handled in the same manner as with cattle.

### Encephalomyelitis:

Both Eastern and Venezuelan types of viral encephalomyelitis have been reported in Guyana. Accurate differential diagnosis of CNS disturbances in horses is essential as the viral encephalomyelitis, rabies, trypanosomiasis and cerebral babesiosis may have similar clinical signs.

Hemagglutination inhibition titers were run on 46 sera for Eastern

TABLE X

## Serological Testing of Horses in Guyana

District	No.	Sex	Age	<sup>1</sup> PCV	<sup>2</sup> VEE	<sup>3</sup> EEE	<sup>4</sup> EIA	<sup>5</sup> <u>B. equi</u>
Coastal								
Golddigings	1	F	1½	23	80	40	+	5
"	2	F	6 mo	29	20	40	+	40
"	3	M	1	36	-	-	-	-
"	4	F	7	40	-	-	+	40
"	5	F	1	32	20	-	+	160
Kabawer	6	F	10	26	-	-	+	640
"	7	M	Aged	37	20	20	+	5
"	8	M	10	30	20	-	+	20
"	9	M	10	31	-	-	+	-
"	10	M	10	33	-	-	+	-
Rupununi								
Karasabi	11	M	5	36	-	-	-	20
"	12	M	5	30	-	10	-	-
"	13	M	3½	33	-	-	-	-
"	14	M	8	33	-	-	-	-
"	15	M	10	28	20	10	+	-
"	16	M	7	30	20	20	-	5
Aishalton	17	M	10	30	10	-	+	10
"	18	M	17	26	-	-	+	5
"	19	M	3	30	40	40	+	-
"	20	F	5 mo	39	20	-	-	40
"	21	M	7	34	40	-	+	10
Dadanawa	22	*M	3	37	40	-	-	-
"	23	M	11	33	20	40	+	40
"	24	M	7	36	-	-	+	20
"	25	M	1	31	-	-	+	5
"	26	M	7	30	-	10	+	5
"	27	M	2½	33	-	10	-	5
Manari Outstn.	28	M	3	32	40	40	+	-
"	29	F	7	31	-	-	+	10
"	30	M	3	40	-	40	-	10
"	31	M	6	36	-	40	+	80
"	32	M	7	35	-	-	+	-
"	33	M	5	36	20	-	+	-
"	34	M	6	36	10	-	+	5
Meetizur	35	M	1 wk	43	80	10	+	40
"	36	F	2½	46	20	-	-	5
"	37	F	3 mo	47	40	-	-	-
"	38	F	6	33	40	-	+	10
"	39	F	9	39	20	-	+	-
St. Ignatius	40	M	8	21	10	-	+	40
"	41	F	8	37	20	-	+	20
"	42	M	3	31	-	-	+	-
"	43	M	5	33	-	-	+	5
"	44	F	4	27	-	-	+	-
"	45	M	Aged	25	10	-	+	80
"	46	M	12	26	20	20	+	320

\* Imported horse

TABLE X (Cont'd)

- <sup>1</sup> PCV = packed erythrocyte volume determined by microhematocrit
- <sup>2</sup> VEE = Venezuelan Equine Encephalomyelitis reciprocal of hemagglutination inhibition test titer
- <sup>3</sup> EEE = Eastern Equine Encephalomyelitis reciprocal of hemagglutination test titer
- <sup>4</sup> EIA = Equine Infectious Anemia immuno-diffusion test
- <sup>5</sup> B. equi = Babesia equi reciprocal of complement fixation test titer

(EEE), Western (WEE) and Venezuelan (VEE) encephalomyelitis at the TAMU Department of Veterinary Microbiology Laboratories. Three horses had a titer of 1:10 for WEE; all three also exhibited a titer of at least 1:40 to one of the other two viruses and it is thought that this indicates a cross reaction, and not evidence of WEE being present in Guyana. However, 15 of 46 exhibited titers of 1:10 or higher to EEE and 25 of 46 for VEE. It is likely that some cross reactivity was also present but evidence presented in Table X indicates the recent presence of both organisms within Guyana.

It is recommended that valuable horses be vaccinated annually or bi-annually against Eastern and Venezuelan encephalomyelitis, and upon diagnosis of the disease a vigorous vaccination program be instituted in the district where diagnosed. To further prevent the spread of disease, if Venezuelan encephalomyelitis is diagnosed, strict quarantine of horse movement from that district is advocated.

#### Equine Infectious Anemia:

Clinical evidence did not indicate a high prevalence of equine infectious anemia (EIA) in Guyana. At the Texas State Veterinary Diagnostic Laboratory, College Station, Texas, the agar gel immuno-diffusion test (Coggins test) was run on 46 sera; 34 were positive for EIA. Sera collected for this test was taken from horses in West Berbice and the Rupununi. The prevalence of disease seemed to be equally high in all areas of the country except for Karasabi, Rupununi where only 1 of 6 (16.7%) horses were serologically positive as compared to 33 of 40 (82.5%) in other areas tested as indicated in Table XI.

Due to the small number of horses tested, it is not known whether vector-borne diseases are less of a problem in Karasabi than in other areas of the country, or, due to sampling methods, negative horses were selected at Karasabi and a high percentage of positive horses elsewhere. The serological prevalence of vector-borne diseases is indicated in Table XI.

It would seem that EIA may be an important factor in the general poor condition exhibited in horses in the country. This lack of stamina and chronic poor doing would make the horses more susceptible to effects of poor nutrition and infectious disease.

TABLE XI

Comparison of Vector-Borne Diseases of Horses in Guyana as Indicated by Serological Means

	<u>VEE</u>		<u>EEE</u>		<u>EIA</u>		<u>B. equi</u>	
Karasabi	2/6	33.3*	3/6	50.0	1/6	16.7	2/6	33.3
Rest of Country	23/40	57.5	12/40	30.0	33/40	82.5	28/39	71.8

\* number positive/number tested

percent positive

### Brucellosis:

Three horses with fistulous withers and/or pollevil were tested serologically for brucellosis by the card test. All were negative.

### Tetanus:

Tetanus is present in Guyana and care should be taken to routinely use tetanus antitoxin with all surgical producers or puncture-type wounds in horses. Valuable horses should be immunized with toxoid. The practice of packing wounds with fresh cow or horse dung should be discouraged.

### Nutrition:

As with other species, poor nutrition of horses could be considered the number one medical problem throughout the country. Serum calcium and phosphorus levels were determined at the Department of Pathology laboratories at TAMU. Sera from 15 horses were found to contain  $11.44 \pm 2.13$  mg/dl calcium with a range of 9.8 to 18.1. Sera from 18 horses were found to contain  $4.96 \pm 2.06$  mg/dl phosphorus with a range of 2.85 to  $>10$ . It therefore seems unlikely frank calcium or phosphorus deficiencies are likely to occur at least in those horses having access to phosphorus supplements. The status of trace minerals in the diet of horses in Guyana is unknown but there was no clinical evidence of disease caused by trace mineral deficiency.

In most areas of the country where horses are utilizing unimproved pastures without concentrate supplementation, the protein and caloric intake is generally insufficient to allow for normal growth rates and to allow energy to be used for much work. The pony-type horse such as is often seen, especially in the Rupununi, is probably the only class of horse which will survive the environment without supplementation. It is unlikely the "breeding up" of horses with outside stock having greater stamina will be successful without the addition of concentrates to the diet.

## VETERINARY SERVICES IN GUYANA

Two important deficiencies exist in veterinary services in Guyana. There is a lack of continuity of veterinary service and a well equipped diagnostic center.

Due in part to the inability of government to attract and keep competent veterinarians, a lack of continuity exists. This lack of continuity requires that each veterinarian entering an area must acquaint himself with local disease conditions without benefit of knowledge acquired over the years.

A staff of less than adequate size and the rapid shifting of veterinarians from one area of the country to another also contributes to this



lack of continuity. In order to attract and keep the quality of veterinarians desired, it will be necessary to provide remuneration and working conditions in line with that provided for similar qualified personnel in government and to take into account the wages provided in countries of similar development. The necessity for young veterinarians to have to hold outside jobs, as well as their duties for the ministry, in order to provide for their families is ridiculous.

No competent veterinary service can exist without the aid of a diagnostic laboratory. This laboratory must consist of a facility which will allow for diagnostic procedures and which contains equipment to carry out the work as well as personnel well trained in diagnostic techniques. The proposal for establishing such a center in Mon Repos near the proposed center for the training of field veterinary assistants is good, as personnel associated with the diagnostic center may be able to take part in the training program.

Three more field veterinary officers are needed; one in the Rupununi; one in Berbice and a third in the West Coast Demerara, Essequibo. Regular veterinary service must be provided for Matthews' Ridge and Ebini.

The idea of Veterinary field assistants is a good one. However, the present livestock assistants are not as effective as they should be. This lack of effectiveness is in some degree due to the failure of continuing and direct supervision by the respective veterinary officers. Having more veterinary officers and a program setting down duties and responsibilities of the livestock assistants will be necessary to get the full value from these men. A more careful selection of men to be trained in this area is necessary.

The livestock assistant has a great opportunity for extension work in his area, but I have found that many do not even know the names of the farmers living in their districts even after a residence of 1 or 2 years.

Little or no efforts are placed on extension work with the young. Reestablishment of 4-H clubs, young farmers' groups, etc. would be desirable. The livestock assistant, with guidance, could be instrumental in establishing such groups. Without such programs to interest the young in agricultural pursuits, the highest quality young men and women go into other fields of endeavour. It is from work with rural youth that future veterinarians, livestock assistants and other agriculturists should come.

## ACKNOWLEDGMENTS

In the course of this study a great number of persons were involved in the collection and evaluation of data. It will not be possible to acknowledge all of the people who contributed to this study; however, I will attempt to recognize some of those whose work was most important to the study.

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Thomas M. Craig  
D. V. M., M. S.

ITVM PUBLICATIONS  
(1968-1978)

1. KUTTLER, L. L., ZARAZA, H. and ROBERTS, E.D.: Hematologic and Clinical Response to Anaplasmosis Vaccines and the Comparative Efficacy of These Vaccines, As Measured by Field and Experimental Challenge. Proceedings of the Fifth National Anaplasmosis Conference, Stillwater, Oklahoma, (February 28-29, 1968): 39-49.

Twenty, 3-month-old calves were divided in 4 equal groups. Group 1 was inoculated with an attenuated Anaplasma marginale; group 2 received an A. marginale adjuvant vaccine; group 3 was infected with virulent A. marginale followed by treatment; and group 4 remained as unvaccinated controls. All animals were moved into an Anaplasma endemic zone 3 months later and allowed to undergo natural field challenge. Evidence of acute anaplasmosis was observed in all calves, except those premunized by virulent A. marginale. No significant evidence of protection was produced by either the attenuated A. marginale or the adjuvant vaccine when compared to the unvaccinated controls. The group premunized with virulent A. marginale failed to respond to natural exposure.

Hematologic response to virulent, attenuated, and killed A. marginale vaccines was measured in 18 mature cattle divided into 3 groups. The group receiving virulent A. marginale was treated 25 days after infection (Burroughs Wellcome Compound 356C61). No death losses occurred in this group, but moderate infections were observed to result in a significant reduction of PCV. The attenuated A. marginale vaccine produced a low level parasitemia, a marked serological response as measured by the complement-fixation (CF) test, and a very slight drop in PCV, which was not significantly different from values observed in an unvaccinated, non-infected, control group. The group receiving adjuvant vaccine showed only a low level, transient, CF serological response.

An experimental challenge was administered 8 weeks after vaccination to cattle receiving the attenuated and adjuvant vaccines, along with a group of 5 unvaccinated controls. All controls reacted to challenge with severe acute signs of anaplasmosis. One animal was allowed to die, a second would probably have died had it not been treated. Cattle receiving the attenuated vaccine showed no signs of active infection resulting from challenge. Cattle receiving the adjuvant vaccine reacted to challenge, but less severely than did the controls.

2. ZARAZA, H. KUTTLER, L. L. and ROBERTS, E. D.: Respuesta Hematologica y Clinica a Diferentes Vacunas de Anaplasmosis y la Eficacia Comparativa de Estas, Evaluadas por la Inoculacion Experimental. Revista ICA, (December 1968), 3, (4): 323-331. (Spanish translation of above.)

3. CARSON, C. A.: An Antigenic and Serologic Comparison of Two Virulent Strains and an Attenuated Strain of Anaplasma marginale. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, August 1969.

An antigenic and serologic study was conducted using virulent strains of Anaplasma marginale from Texas and Colombia and an attenuated strain of Anaplasma marginale. Soluble antigens of the three A. marginale strains were compared by agar gel diffusion and immunoelectrophoresis. Serum proteins from calves infected with each of the three A. marginale strains were separated electrophoretically and reacted with rabbit anti-bovine serum in immunoelectrophoresis systems.

No differences between the soluble antigens of the three A. marginale isolates were detectable by agar gel diffusion. All three antigens moved to the same mobility zone in agar gel electrophoresis systems and each antigen formed an arc of precipitation when reacted with serum from calves infected with homologous or heterologous strains of A. marginale.

A beta and a gamma serum protein component, not exhibited in normal bovine serum, were present in the serums of animals infected with either of the virulent A. marginale strains or the attenuated strain.

4. GONZALEZ, E. F. and TODOROVIC, R. A.: Ultraestructura de la Babesia bigemina Revelada por el Microscopio Electronico. Proceedings of the VII Congreso Nacional de Medicina Veterinaria y Zootecnia, Ibague, Colombia, (November 8-12, 1969).
5. KUTTLER, K. L.: Serial Passage of an Attenuated Anaplasma marginale in Splenectomized Calves. Proceedings of the 73rd Annual Meeting of the USAHA, Milwaukee, Wisconsin, (October 12-17, 1969): 131-135.

Twelve serial passages of an attenuated Anaplasma marginale were made in splenectomized calves by blood inoculation. The severity of infection produced at the twelfth passage level in 4 splenectomized calves was compared to the infection occurring in 4 similar calves at a second passage level. Significantly higher parasitemias and lower packed cell volumes occurred in the twelfth passage group, suggesting an increased virulence. No deaths occurred among animals of the second passage group; whereas, 1 of 4 died in the twelfth passage group.

6. KUTTLER, K.L., ADAMS, L. G. and ZARAZA, H.: An Epidemiologic and Geographic Survey of Anaplasma marginale and Trypanosoma theileri in Colombia. Proceedings of the 106th Annual AVMA Convention, Minneapolis, Minnesota, (July 1969). Journal of the American Veterinary Medical Association, (June 1, 1969), 154: 1398, (abstract).

Anaplasmosis complement-fixation tests, packed cell volumes, and stained blood smears were made on 603 cattle located at 5 experiment station farms in Colombia. These farms were situated in differing climatic zones varying from 2,600 meters to 13 meters in altitude and from 13°C to 28°C in mean temperature. Specific reference was made to breed susceptibility, the influence of age, and climatic condition on the incidence and severity of infection.

A direct correlation was noted between mean temperature and incidence of anaplasmosis. At 13°C the incidence was nil; whereas, at 28°C over 90% infection was noted. The mean temperature is directly associated with altitude.

Incidence of infection in enzootic areas was generally greater in older animals, but the effect of infection as characterized by anemia was more noticeable in young animals. The incidence of anaplasmosis in European breeds did not appear greatly different when compared to native and Zebu cattle, but in some instances PCVs were significantly lower in European breeds. This was most marked at the lower elevations.

Blood cultures for Trypanosoma theileri from 71 cattle at 2 experiment stations resulted in a pattern of infection similar to anaplasmosis. A high incidence of infection was noted at the lower elevation with a high mean temperature and no evidence of infection at 2,600 meters with a low mean temperature.

7. KUTTLER, K. L. and ZARAZA, H.: Premunization with an Attenuated Anaplasma marginale. Proceedings of the 73rd Annual Meeting of the USAHA, Milwaukee, Wisconsin, (October 12-17, 1969): 104-112.

An attenuated Anaplasma marginale infection had been established in 21 calves and 12 mature cattle. The resulting infections were found to be significantly less severe than virulent A. marginale in 12 calves and 5 mature cattle. A slightly milder response to the attenuated A. marginale occurred in calves at Bogota with a mean temperature of 14°C when compared to calves similarly infected at Palmira with a mean temperature of 24°C.

Calves and mature cattle previously premunized with the attenuated organism appeared to be immune to virulent challenge with a Colombian isolate resulted in evidence of acute anaplasmosis in both vaccinated and non-vaccinated animals.

8. TODOROVIC, R. A., ADAMS, L. G. and ROBERTS, E. D.: A Study of Bovine Babesiosis in Colombia, South America. Proceedings of the 106th Annual AVMA Convention, Minneapolis, Minnesota, (July 1969). Journal of the American Veterinary Medical Association, (June 1, 1969), 154: 1399, (abstract).

Our research program on bovine babesiosis is a part of the Institute of Tropical Veterinary Medicine, College of Veterinary Medicine, Texas A&M University, with the research program being sponsored by the Rockefeller Foundation and conducted at the Laboratorio de Investigaciones Medicas Veterinarias laboratories, Bogota, Colombia, in cooperation with the Instituto Colombiano Agropecuario. This research effort is directed mainly toward the study and control of bovine babesiosis and the training of Colombian veterinarians and graduate students involved in these research projects.

Although bovine babesiosis is eradicated in the United States, the disease still occurs in most of the world and is of great importance as a threat to livestock industry, especially in the tropical areas of Latin American countries. In Colombia, babesiosis was first described by Lleras (1908) and later recognized as a widely distributed disease, causing great losses in purebred dairy cattle imported into enzootic areas. At the present time the incidence of babesiosis in Colombia is difficult to estimate. The disease exists as a mixed infection of Babesia bigemina, Babesia argentina, and Babesia major, and the incidence of infection appears to be related to the occurrence and activity of the tick vectors at the various altitudes.

The experiments were carried out to identify the existing Babesia species occurring in Colombia by morphologic, immunoserologic, pathologic, and chemotherapeutic methods. The immunoserologic relationship of Babesia spp. and strains were studied by gel-double diffusion precipitation, immunoelectrophoresis, and fluorescent antibody techniques. Attempts were made to develop a sensitive and practical serologic test for the diagnosis of the latent Babesia infection. Several groups of intact and splenectomized calves were inoculated with various antigens isolated from the blood of cattle with acute babesiosis and the blood from patent carriers, respectively. Response to vaccination, premunition, and challenge by tick-borne Babesia was recorded. The results of these experiments were discussed.

9. VIZCAINO, O. G., TODOROVIC, R.A. and ADAMS, L. G.: Diagnostico de Babesiosis Bovina en Frotis Delgados de la Sangre. Proceedings of the VII Congreso Nacional de Medicina Veterinaria y Zootecnia, Ibague, Colombia, (November 8-12, 1969).
10. ZARAZA, H., KUTTLER, K. L. and ROBERTS, E. D.: Efectos de la Descarga Natural de Anaplasma marginale en Terneros Vacunados y no Vacunados. Revista JCA, (September 1969), 4, (3).

11. ADAMS, L. G., HIPOLITO, O., MORALES, H., GONGORA, S. and JONES, L. P.: Dermatofilosis Bovina (Estreptotricosis cutanea) en Colombia. Revista ICA, (March 1970), 5, (1): 3-16.

Four cases of bovine dermatophilosis were diagnosed in Cordoba, Colombia, and confirmed by bacteriological culture methods. Macroscopic and microscopic descriptions were made of the lesions caused by Derma-  
tophilus congolensis.

12. ADAMS, L. G. and KUTTLER, K. L.: Toxicity of Alpha-Ethoxyethylglyoxal Dithiosemicarbazone in Cattle. American Journal of Veterinary Research, (August 1970), 31: 1493-1495.

Alpha-ethoxyethylglyoxal dithiosemicarbazone, administered 10 consecutive days at the dose rate of 5 mg/kg/day, caused axonal and myelin degeneration of the vagus nerve in 2 of 7 calves. Of the 7 experimental calves, 6 died of tympanites.

13. ADAMS, L. G. and TODOROVIC, R. A.: A Study of the Pathogenesis of Anaplasmosis in Intact Calves: Including Clinical, Clinical Pathological, Serological, and Immunofluorescent Techniques. Proceedings of the VI Congreso Panamericano de Medicina Veterinaria y Zootecnia, Santiago, Chile, (September 28- October 3, 1970): 37, (abstract).

Twelve, 4-month-old, male, hemotropic disease-free, Holstein calves were inoculated subcutaneously with blood containing a Colombian isolate of Anaplasma marginale. Previous to inoculation 3 control samples were taken for bone marrow and blood determination.

Thereafter, samples were collected every 2 days and 1 calf was euthanatized every 2 days to collect a complete set of tissues for gross and microscopic pathological lesions, as well as for the immunofluorescent study using the indirect technique. Results obtained are discussed, except those related to immunofluorescent study.

14. CARSON, C. A., ADAMS, L. G. and TODOROVIC, R. A.: An Antigenic and Serologic Comparison of Two Virulent Strains and an Attenuated Strain of Anaplasma marginale. American Journal of Veterinary Research, (June 1970), 31, (6): 1071-1078.

Soluble antigens of 3 Anaplasma marginale strains were compared by agar gel diffusion and immunoelectrophoretic techniques. Serum proteins from calves infected with each of the 3 A. marginale strains were separated electrophoretically and tested with rabbit anti-bovine serum in immunoelectrophoretic systems. There was no detectable difference between the soluble antigens or the 3 A. marginale strains. A beta globulin arc, which was not detectable in normal bovine serum, was present in serum of acutely affected calves, and a gamma globulin arc was lengthened in the latter serum as compared with that in serum of normal calves.

15. GADIR, F. A., HIDALGO, R. J. and KUTTLER, K. L.: Complement-Fixation Antigen Production for Theileria in White-Tailed Deer (Odocoileus virginianus). American Journal of Veterinary Research, (May 1970), 31: 879-885.
16. KUTTLER, K. L. and ADAMS, L. G.: Comparative Efficacy of Oxytetracycline and a Dithiosemicarbazone in Eliminating Anaplasma marginale Infection in Splenectomized Calves. Research in Veterinary Science, (July 4, 1970), 2, (4): 339-342.

Comparisons between oxytetracycline and a dithiosemicarbazone (356C61) were made in 11 splenectomized, Anaplasma marginale infected calves. Oxytetracycline was administered at the rate of 11 mg/kg intravenously (i.v.) for 5 and 10 consecutive days. Compound 356C61 was administered at the rate of 5 mg/kg i.v. for 5 and 10 consecutive days.

Compound 356C61 appeared to be relatively more effective in the treatment of anaplasmosis, as indicated by the relative increase in packed cell volume (PCV) following treatment, and by the apparent elimination of the carrier status in animals receiving the 10 daily treatments. Compound 356C61 administered daily for 10 consecutive days resulted in rumen atony, tympanites, and death.

17. KUTTLER, K. L., ADAMS, L. G. and ZARAZA, H.: Estudio Epizootiologico del Anaplasma marginale y el Trypanosoma theileri en Colombia. Revista ICA, (June 1970), 5, (2): 127-148. (Spanish translation of: Kuttler, K. L., Adams, L. G. and Zaraza, H.: An Epidemiologic and Geographic Survey of Anaplasma marginale and Trypanosoma theileri in Colombia.)



18. KUTTLER, K. L. and ZARAZA, H.: A Preliminary Evaluation of a Dithiosemicarbazone for the Treatment of Anaplasmosis. *Research in Veterinary Science*, (July 4, 1970), 2, (4): 334-338.

Trials were conducted on 3 splenectomized calves treated with a single intravenous (i.v.) inoculation of a dithiosemicarbazone (356C61) using 5 mg/kg, at different stages of induced anaplasmosis infection. When compared to an untreated control, this compound was effective in reducing the severity of the infection. Hematological response was least severe in the animal receiving treatment before signs of parasitemia or a decrease in packed cell volume had occurred.

Treatment with compound 356C61 (5 mg/kg i.v.) of 5 splenectomized calves and 6 intact adult cattle early in the course of an artificially induced Anaplasma marginale infection prevented death loss and reduced the severity of the subsequent reaction when compared with non-treated controls.

19. TODOROVIC, R. A.: Babesiellosis Bovina en Australia. *Revista de la Facultad de Medicina Veterinaria y de Zootecnia*, (1970), 32, (1 & 2): 45-59.

Bovine babesiosis is still of great importance as a threat to the livestock industry in Australia. Due to the complexity of the epidemiology of this disease and other factors, the eradication of this hemoprotozoan malady is not possible at the present time.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) is actively engaged in control and research on Babesia. Other research and teaching institutions involved in the same problem include: the University of Queensland; New South Wales, Department of Agriculture, Cattle Tick Research Station; Queensland State Department and Animal Health Station. All of these research projects on Babesia are sponsored mainly from the Government of Australia.

The Australian research workers have contributed more than a hundred scientific publications on the various areas of Babesia research; they are foremost in this field and the best trained in the world. The research laboratories are equipped with modern scientific tools, and staffed with well-trained technicians who successfully operate these instruments. The facilities are excellent and designed particularly for Babesia research. (Slides of these facilities are available for those who are interested.)

The experience from this visit and knowledge obtained through discussion with Australian scientists working on different research projects will be invaluable for organizing a similar research program on Babesia in Colombia, South America. Furthermore, the Australian scientists with whom I visited all realized the importance of our mission in South America and expressed their willingness to cooperate with us in any manner in the future. They will be able to come to Colombia and spend time on short- or long-term assignments if funds are available.

20. TODOROVIC, R. A., ADAMS, L.G. and GONZALEZ, E. F.: Bovine Babesiosis: Its Problem and Control in Colombia, South America. Proceedings of the III Congreso Nacional de Medicina Veterinaria y Zootecnia, Lima, Peru, (May 17-23, 1970): 105-107, (abstract).
21. TODOROVIC, R. A., ADAMS, L. G., VIZCAINO, O. G. and GONZALEZ, E. F.: Research and Control of Bovine Babesiosis in Colombia, South America. Proceedings of the VI Congreso Panamericano de Medicina Veterinaria y Zootecnia, Santiago, Chile, (September 28 - October 3, 1970): 36, (abstract).

Research was carried out to develop an effective program for the control of bovine babesiosis in Colombia.

Experiments were carried out at the Palmira Instituto Colombiano Agropecuario (ICA) experimental station in Valle del Cauca (altitude 1,000 meters) to produce co-infectious and sterile immunity against bovine babesiosis. Calves randomly selected were divided into 4 groups according to the experimental design used to evaluate the immunoserological responses to vaccination against babesiosis and tick-borne challenge. The degree of this immunity was determined by tick- and blood-borne challenge. The percentage of parasitemia (P), body temperature (T), and percentage of mortality (M) were used as the basis for comparing the reaction produced after vaccination and challenge. Experiments were conducted to evaluate the prophylaxis, therapy, effects, dosage, route of injection, toxicity, and response of the animals injected with a new Burroughs Wellcome babesiacidal drug, No. 4A65.

On the basis of the observations made from these experiments, conclusions can be drawn that some degree of sterile immunity exists, besides the well-known co-infectious (premunition) immunity in Babesia infections. To understand the exact mechanism of this type of immunity, more work needs to be done. The degree of resistance and the duration of immunity in relationship to different environmental conditions, strain differences, and the pathogenicity of the Babesia spp., and the quality of tick-borne challenge need to be determined.

22. TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Immune Response of Cattle Vaccinated Against Babesiosis in Colombia, South America. Proceedings of the 107th Annual AVMA Meeting, Las Vegas, Nevada, (June 22-26, 1970).

Attempts to produce co-infectious and sterile immunity in cattle against Babesia infections have been carried out by vaccinating animals with live or killed Babesia vaccines at Palmira, Valle del Cauca, Colombia (altitude 1,000 meters). Immune responses of the vaccinated animals were evaluated by several immunoserologic methods. The degree of resistance to tick-borne challenge (Boophilus microplus naturally infected with Babesia spp.) was determined by the percentage of recovery to normal parameters used in this study.

According to the experimental design used, a total of 110 animals were divided in 5 experimental groups to ascertain the immunologic responses. The first group consisted of 20 male, 85 kg., Holstein, 3-month-old calves which were preimmunized with Babesia bigemina, Babesia argentina, and 4 weeks later exposed to tick-borne (Boophilus microplus) challenge. The second group consisted of 20 male, 95 kg, Holstein, 4-month-old calves subdivided into 4 groups and vaccinated with a killed Babesia vaccine derived from the erythrocytes and plasma, respectively, of animals acutely infected with B. bigemina and B. argentina. The animals were inoculated with vaccine with or without Bacto-Adjuvant Complete H 37 Ra. The third group of 40 male, 80 kg., Holstein, 3-month-old calves was divided into sub-groups. The first sub-group consisted of 20 animals which were preimmunized with B. bigemina and B. argentina and 8 days later were treated with a new experimental babesiacidal drug. The second sub-group which consisted of 20 animals was simultaneously preimmunized with Babesia spp. and Anaplasma marginale and later treated with their respective specific drugs. The fourth group consisted of 20 female, 75 kg, Holstein, 3-month-old calves prophylactically treated with drug No. 4A65 and 3 weeks later exposed to B. microplus naturally infected with B. bigemina and B. argentina. The fifth group consisted of 10 animals used as controls.

Responses to vaccination and tick-borne challenge were evaluated by packed cell volumes, percentage of parasitemia, body temperatures, body weight, complement fixing antibody titers, general physical conditions, and percent recoveries after tick-borne challenge.

Results in general indicate that resistance to babesiosis can be produced by co-infectious or sterile immunity. Experiments in prophylaxis, based on residual action of the babesiacidal drug, have given consistent and satisfactory results. In the future, it may be possible to develop control programs against bovine babesiosis based on these observations. The present status of these studies was described.

23. ADAMS, L. G. and FERREIRA, W. L.: Necrobacilosis Neo-Natal en Ovinos. Revista ICA, (September 1971), 6, (3).

Five cases of ovine neo-natal necrobacilosis, in the Savannah of Bogota, were diagnosed in lambs less than 2 weeks of age. Macroscopic and microscopic lesions were described and the diagnosis was confirmed by bacteriological culture techniques. This report constitutes the first known notice of the disease in neo-natal lambs in Colombia.

24. BISHOP, J. P., THOMPSON, K. C., CORRIER, D.: Aislamiento, Separacion y Preservacion de Babesia bigemina del Valle del Sinu. Resumen de los Trabajos Presentados al VII Congress Nacional de Medicina Veterinaria y de Zootecnia, Circuta, Colombia, November, 1971.

Se describe en este trabajo el origen de una cepa estable y pura la B. bigemina usada para efectos investigativos en el Laboratorio de Investigaciones Medicas Veterinarias de Bogota y en el Laboratorio de Investigaciones Veterinarias Tropicales de Monteria, pertenecientes al Instituto Colombiano Agropecuario (ICA).

Los experimentos se efectuaron con el proposito de separar la B. bigemina de otros organismos contaminantes. El metodo consistio en hacer pasajes de sangre contaminada a traves de cinco terneros esplenectomizados. El primer ternero fue inoculado con sangre que portaba diversos hemoparasitos y las subsiguientes inoculaciones se hicieron cuando las extensiones sanguineas del ternero inoculado, mostraban formas de Babesia bigemina.

Se hicieron cinco pasajes de sangre en seis y medio dias. Despues del cuarto pasaje fue aislada Babesia bigemina pura, las formas de Babesia argentina, Babesia major y Anaplasma marginale fueron eliminadas en el curso del estos pasajes sucesivos. Se congelo una cepa para estable de B. bigemina.

25. VIZCAINO, O. G., THOMPSON, K. C., MATEUS, G.: Aislamiento de Babesia Argentina Utilizando Larvas de Boophilus microplus, Resumen de los Trabajos Presentados al VII Congreso Nacional de Medicina Veterinaria y Zootecnia, Cucuta, Colombia, November 1971.

Las garrapatas, especialmente las de la familia Ixodae, transmiten en sus fases de desarrollo, numerosos agentes infecciosos a los animales domesticos. El ejemplo mas evidente de este fenomeno es el de la transmision de protozoarios del tipo de las babesias.

Al inocular animales susceptibles, con sangre de animales portadores de hematozoarios se desarrollan, segun el periodo prepatente del agente especifico, los cuadros clinicos de babesiosis o de anaplasmosis.

En Colombia la babesiosis bovina es ocasionada por tres generos de babesias: Babesia bigemina, B. argentina y B. major transmitidas principalmente por la garrapata Boophilus microplus, al igual que sucede en otras areas tropicales y subtropicales.

El objetivo de este trabajo fue aislar una cepa de B. argentina en estado puro, libre de otros protozoarios, utilizando Larvas de Boophilus microplus. El aislamiento de la cepa pura de B. argentina se hace necesario para producir antigenos especificos utilizables en pruebas serologicas. El trabajo se realizo en el LIMV de Bogota y la Granja de Turipana en Monteria.

26. BISHOP, J. P.: Immune Response of Cattle Inoculated With Irradiated Babesia bigemina. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, December, 1971.

Babesia bigemina parasitized blood exposed to varied doses of gamma radiated up to 60 kRad was inoculated into calves. Calves infected with  $1 \times 10^{10}$  B. bigemina parasitized erythrocytes exposed to doses up to and including 30 kRad developed progressive parasitemias. Some calves receiving  $1 \times 10^{10}$  parasitized erythrocytes irradiation at levels of 36 and 42 kRad did not develop progressive infections. Progressive infections were prevented by exposure to irradiation at 48 kRad or higher. Subinoculations into susceptible splenectomized calves from parasites thus treated failed to produce active infections.

A degree of acquired resistance to infection with B. bigemina developed in calves after 1 inoculation with B. bigemina parasitized blood irradiated at 48 and 60 kRad. The resistance was sufficient to suppress multiplication of the Babesia and to permit calves to survive otherwise severe clinical infections with nonirradiated parasites. There was also less erythrocytic destruction and a smaller increase in rectal temperatures following challenge. Presumably, the irradiated parasites were responsible for the development of resistance since irradiated nonparasitized blood did not produce a discernable acquired resistance.

The acquired resistance to infection with B. bigemina developed in calves inoculated with  $1 \times 10^{10}$  B. bigemina irradiated at 48 and 60 kRad was similar to the acquired resistance developed in calves inoculated with  $1 \times 10^{10}$  nonirradiated B. bigemina. It seems likely that the protective immunity produced with irradiated B. bigemina may be similar to that produced with living pathogenic B. bigemina developed in calves inoculated with  $1 \times 10^{10}$  B. bigemina irradiated at 48 and 60 kRad was much greater than the acquired resistance to infection developed in calves inoculated with  $1 \times 10^{10}$  heat-killed B. bigemina. Thus, it seems likely that immunization with irradiated Babesia may provide the special immunological properties of living parasites important for producing a strong immunity while suppressing the pathogenic effects of the parasite. The Babesia parasites could be irradiated and frozen without apparent loss of immunizing properties.

27. DALEY, C.A.: A Sequential Study of the Pathogenesis of Disease Caused by Trypanosoma vivax in Experimentally Infected Calves, Utilizing Clinical, Pathological, Histopathological and Immunofluorescent Techniques. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, May 1971.

Trypanosoma vivax obtained from a clinically sick cow near Neiva, Colombia, was passed in a sheep and a calf and inoculated into the jugular vein of 14 Holstein-Friesian calves. Fever occurred by 24 hours, and recurring parasitemia commenced after 72 hours. Associated with the first and subsequent parasitemias were decreases in hemoglobin, PCV, M:E ratio, serum albumin, A:G ratio and neutropenia.

All calves exhibited gradual weight loss by 2 weeks and later sub-mandibular edema usually became evident. Consistent post mortem lesions seen after 4 weeks were conspicuously hypertrophied, edematous lymph nodes, hypertrophied hemal lymph nodes, emaciation, rounded right heart, palpably firm liver, atrophied thymus and hypertrophied femoral bone marrow.

Associated with T. vivax of the infecting inoculum and succeeding parasitemias were generalized endothelial hypertrophy and mononuclear cell infiltration along blood and lymph vessels with proteinuria and bone marrow hyperplasia. At 3 weeks there were aggregations of macrophages containing engulfed material distributed along capillaries in pulmonary interalveolar tissue, and this lesion in combination with the anemia and apparent cardiac insufficiency were thought important in the development of anoxia, and probably contributed to the single fatality observed.

28. GONZALEZ, E. F., TODOROVIC, R. A. and ADAMS, L. G.: Ultraestructura de la Babesia bigemina. Revista ICA, (March 1971), 6, (1): 89-112.

The morphology and some aspects related to the reproductive and feeding mechanism of Babesia bigemina were studied by means of electron microscopy.

Babesia bigemina was isolated from naturally infected cattle in the Valle del Cauca, Colombia, and maintained in splenectomized calves in the Laboratorio de Investigaciones de Medicas Veterinarias in Bogota. Blood samples were collected from the splenectomized animals at a time when the percentage of parasitized erythrocytes was 25%, and these samples were used for electron microscopic studies.

By means of the electron microscope, different stages of B. bigemina were revealed, such as oval, conoid, and most commonly pear shaped. The sizes of these forms were 2.5 to 6.5 microns in length by 2.3 microns in width. The young forms of the parasite were 1.5 to 2.5 microns. All these forms of parasites are surrounded by a dense cytoplasmic membrane which contained endoplasmic reticulum in the form of vesicles; these vesicles are composed of granules of different density. The endoplasmic reticulum appears as a homogenous mass with transparent vacuolar structures which are oval and spherical in shape. In addition to the endoplasmic reticulum, well defined dense polar bodies were found which appeared as oval shaped organelles, which communicated with the conoid part of the parasite by canals. The nucleus was the largest internal structure of the parasite and occupies 1/4 to 1/3 of its body. The nucleus is surrounded by a single membrane. Nucleoli were not revealed by electron microscopy.

Reproduction of B. bigemina appears to be carried out in 2 ways: by budding and binary fission. On the basis of these observations it is not clear which means of reproduction is more predominant. It is possible that both forms take place at the same time.

The feeding mechanism is not apparent. It appears that polar bodies play some role in this mechanism. These polar bodies could assume the function of food reservoirs of the parasite. It was also revealed that food vacuoles are similar to those in malarial parasites. The formation of food vacuoles probably results from an end process of pinocytosis as was described for Plasmodium species. We believe that both processes are involved in the feeding mechanism of Babesia parasites. Results of this study confirm the previously reported observation that there is no formation of pigment granules in Babesia; this implies that digestion of the host hemoglobin is complete; in contrast, malarial parasites form hemozoin, a blood pigment, as an end product of metabolism.



29. KUTTLER, L. L.: Efficacy of Oxytetracycline and a Dithiosemicarbazone in the Treatment of Anaplasmosis. *American Journal of Veterinary Research*, (September 1971), 32, (9): 1349-1352.

The combination of a dithiosemicarbazone (356C61) and oxytetracycline proved more efficacious in the treatment of anaplasmosis than did either drug administered alone. The Anaplasma marginale carrier state in splenectomized calves was suppressed for as long as 120 days and was possibly eliminated by 3 injections of 356C61 (5 mg/kg) and oxytetracycline (11 mg/kg) given simultaneously at 48-hour intervals.

30. KUTTLER, K. L.: Promising Therapeutic Agents for the Elimination of Anaplasma marginale in the Carrier Animal. Proceedings of the 75th Annual Meeting of the USAHA, Oklahoma City, Oklahoma, (October 27, 1971): 92-98.

Two new drugs, a dithiosemicarbazone (356C61) and 3,3'-bis(2-imidazolyl)-carbanilide dihydrochloride (4A65) have been successfully used to treat splenectomized calves with anaplasmosis. Carrier infections were eliminated with 5 or 10 mg/kg 356C61 and 11 mg/kg oxytetracycline when given 3 times at either a 24- or 48-hour interval. In addition, 5 mg/kg 356C61 plus 2 mg/kg 4A65 given 3 times at 24-hour intervals was effective in eliminating Anaplasma marginale infections. Levels of 4 and 6 mg/kg of 4A65 given 3 times at 24-hour intervals has proven successful in eliminating A. marginale infection.

31. KUTTLER, K. L., GRAHAM, O.H. and JOHNSON, S. R.: Apparent Failure of Boophilus annulatus to Transmit Anaplasmosis to White-Tailed Deer (Odocoileus virginianus). *Journal of Parasitology*, (June 1971), 57, (3): 657-659.

Transovarial transmission of anaplasmosis occurred when 2 splenectomized calves were infested with unfed larvae of Boophilus annulatus, but no evidence of infection was detected in 2 intact white-tailed deer after they were infested with other larvae of common origin. All attempts to isolate Anaplasma marginale from the 2 deer by transfer of blood into splenectomized calves were unsuccessful.

32. MULLENAUX, C. H. and ADAMS, L. G.: La Oncocercosis Equina Asociada con el Mal de la Cruz en Colombia: Descripcion de dos casos. Revista ICA, (September 1971), 6, (3).

Two cases of equine fistulous withers were diagnosed in which Onchocerca spp. was found to be present in the affected tissue. One of the horses had a brucellosis antibody titer of 1:50 using the rapid plate agglutination method and, in the same animal, Brucella spp. was cultured from the suppurative materials of the nuchal bursitis of the withers. Macroscopic and microscopic pathological lesions caused by the nematode Onchocerca spp. were described.

33. TODOROVIC, R. A. and ADAMS, L. G.: Serodiagnosis of Babesiosis. Proceedings of the XIX World Veterinary Congress, Mexico City, Mexico, (August 15-22, 1971): 1114-1116, (abstract).

Detection of the carrier state of bovine babesiosis has presented a particularly difficult problem because blood from a high percentage of carrier animals does not contain sufficient Babesia parasites on which to base the diagnosis. In the last two decades fundamental knowledge concerning the immuno-serology of several Babesia spp. has led to development of serodiagnostic procedures for detection of Babesia antibodies. This review summarizes recent advances in the serodiagnosis of babesiosis in infected cattle. Special attention is given to the serologic procedures used in the Laboratorio de Investigaciones Medicas Veterinarias (Bogota, Colombia), in collaboration with the Instituto Colombiano Agropecuario, specifically the complement-fixation test, the double-gel diffusion test, the latex-agglutination and hemo-agglutination tests.

34. TODOROVIC, R. A., GONZALEZ, E., MATEUS, G. and ADAMS, L. G.: Simultaneous Control of Helminths and Parasites in Cattle. Revista de la Facultad de Medicina Veterinaria y Zootecnia, Bogota, (1971), 33: 47-58.

Experiments were conducted at the ICA experimental station in Palmira, Colombia, to evaluate a control program for gastrointestinal and hemotropic parasites. As a result of effective premunition, vaccination, and treatment techniques, animals had a high degree of resistance to babesiosis and anaplasmosis infections. However, the animals in the control group had clinical infections of Babesia and Anaplasma and high infestation with gastrointestinal parasites.

The importance of simultaneous control of gastrointestinal and hemotropic parasites is pointed out and methods to control these parasites are given.

35. TODOROVIC, R. A., VIZCAINO, O. G. and ADAMS, L. G.: Determinacion de Anticuerpos de Babesia por la Tecnica de la Fijacion del Complemento. Revista ICA, (1971), 6: 213-233.
36. VIZCAINO, O., TODOROVIC, R.A. and ADAMS, L. G.: Caracterizacion Inmunoserologica de Antigenos de Babesia bigemina y Babesia argentina por Fijacion del Complemento, Precipitacion en Gel e Inmunoelectroforesis. Proceedings VII Congreso Nacional de Medicina Veterinaria y de Zootecnia, Cucuta, Colombia, (November 10-15, 1971): 6-7, (abstract).
37. ZARAZA, H. and KUTTLER, K. L.: Comparative Efficacy of Different Immunization Systems Against Anaplasmosis. Tropical Animal Health & Production, (1971), 3: 77-82.

Animal response to anaplasmosis vaccination was measured using an attenuated organism, a killed adjuvant vaccine, and a virulent Anaplasma marginale. A total of 7 calves (2-4 months of age) and 5 heifers (18 months of age) received the attenuated organism; 8 calves were given the adjuvant vaccine; 7 calves were premunized with virulent A. marginale; and 7 calves remained as non-vaccinated controls. The animals were vaccinated at Tibaitata on the Bogota Savannah and later moved to the north coast of Colombia, an anaplasmosis enzootic area.

All vaccination methods produced positive CF results. The live agents resulted in low parasitemias in most instances, although the attenuated organism was particularly mild in the younger animals.

Protection from field challenge was observed in all calves premunized with virulent organism, and in 2 of 5 heifers premunized with the attenuated organism. All other vaccinated animals developed anaplasmosis which was equally as severe as seen in the non-vaccinated controls.

38. CORRIER, D. E.: A Clinical, Serologic and Pathological Study of Concurrent Anaplasmosis and Babesiosis in Experimentally Infected Calves. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1972.

Concurrent and single infections of Anaplasma marginale and Babesia bigemina were studied in 22, 7 month old, male, non-splenectomized Holstein-Friesian calves. Clinical manifestations of disease were mild, consisting primarily of slight fever, poor body condition, and reduced weight gains. Anaplasma marginale appeared to be the more pathogenic of the 2 organisms.

Associated with the appearance of parasitized erythrocytes were decreases in packed cell volume, hemoglobin, albumin:globulin ratio, and serum albumin, and slight increases in the levels of serum bilirubin, serum glutamic oxalacetic transaminase, and alpha and beta serum globulins. Decreases in PCV and hemoglobin concentration were more prolonged and severe in the concurrently infected calves. Complement fixing antibodies for Anaplasma occurred on days 17 to 26 in association with increases in alpha and beta globulins. Complement fixing antibodies for Babesia were first observed on day 12 post inoculation.

Gross lesions observed in the concurrently infected calves included a moderately excessive quantity of yellow fluid in the peritoneal and pleural cavities, moderate lymph node enlargement, splenomegaly and hepatomegaly, moderate renal congestion, and occasional serous atrophy of depot fat.

Hepatocellular degeneration and necrosis were observed in the centrilobular areas of the liver. Lymphoid hyperplasia was observed in the malpighian corpuscles of the spleen and in the lymphoid follicles of the lymph nodes. Hemosiderosis of the spleen, liver, kidney and lymph nodes was attributed to the increased removal of damaged erythrocytes from the circulation with the subsequent release of breakdown products of hemoglobin.

The biological relationship of A. marginale and B. bigemina during the concurrent infection appeared to be one of independency. Neither an inhibitory nor a synergistic relationship was apparent during the investigation. The clinical and pathological manifestations of concurrent infection were more severe than those observed during infection with either of the hemotropic parasites alone, and were attributed to the concurrent infection being additive in nature.

39. HERNANDEZ, J. D., ROBERTS, E. D., ADAMS, L. G. and VERA, T.: Pathogenesis of Hepatic Granulomas in Turkeys Infected with Streptococcus faecalis var. liquefaciens. Avian Diseases, (January-March 1972), 16, (2): 201-216.

The pathogenesis of hepatic granulomas in turkeys has been studied by reproducing the lesions experimentally with Streptococcus faecalis var. liquefaciens isolated during a field outbreak of turkey hepatic granulomas in Colombia. The 170 turkey poults (Bronze) used were 4 weeks old. Groups of poults were inoculated intravenously or orally with 0.1 ml. of a 24-hour culture of S. faecalis var. liquefaciens at a dilution of  $3 \times 10^{10}$  on the McFarland Nephelometer Standard 10. The oral route of inoculation reproduced a disease most similar to the naturally occurring disease.

Clinically, the acute phase of infection was characterized by a high mortality rate in the first to seventh days but only sporadically thereafter. The septicemic phase produced the formation of septic thrombi which localized in various organs, producing infarction with heterophilic infiltration. Once the septicemic phase of the problem passed, the disease was manifested primarily by a focal hepatitis initiated primarily as a focal necrotic cholangial lesion. The biliary epithelium had hyperplastic to degenerative processes which participated in the formation of biliary thrombi. Granulomas were characterized by focal areas of necrosis surrounded by Langhans-type giant cells and macrophages.

40. JONES, F. M.: Control of Anaplasmosis and Babesiosis in Young Cattle. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1972.

A study was conducted on the control of anaplasmosis and babesiosis in young cattle in Colombia. Three groups of 10 calves were used at each of 3 different climatic and geographic areas. One group was vaccinated with an attenuated Anaplasma marginale vaccine and a killed Babesia bigemina, Babesia argentina vaccine. A second group was injected with infected A. marginale, B. bigemina and B. argentina blood that originated from donor cattle from the eastern plains. Five days post inoculation the induced infection was treated by injection of compounds 356C61 (alpha-ethoxy-ethylglyoxal dithiosemicarbazone) and 4A65 (3,3'-bis-(2-imidazolyl)-2-yl) carbanilide dihydrochloride). The third group of calves was used as a control. Calves selected for use at Monteria were not native to that area. All calves were subjected to natural exposure. Ticks were collected and identified at each site.

There was no apparent significant difference in weight gains and resistance to anaplasmosis and babesiosis between groups at any site. At Bugalagrande and Girardot the absence of death losses from anaplasmosis and babesiosis in the control groups indicates that the calves had a pre-existing natural immunity, an acquired non-sterile immunity at the beginning of the study, or no challenge during the study. At Monteria, it was apparent that the vaccinated and preimmunized calves did not develop resistance to anaplasmosis and babesiosis due to the use of antigenically different organisms; the simultaneous injection of the preimmunization drugs at 5 days post inoculation; the lack of sufficient sterile immunity to suppress tick-borne infection; or the inability of the very young calves to develop sufficient resistance.

The identification of Boophilus microplus ticks at all 3 sites confirms reports of this vector in anaplasmosis and babesiosis enzootic areas of Colombia. The significance of Anocentor nitens ticks on Anaplasma and Babesia spp. infected cattle is not apparent at this time.

As a result of this study, it is concluded that the control of bovine anaplasmosis and babesiosis in tropical areas is more complex than previously recognized. More investigation is needed to obtain information on strain antigenicity of A. marginale, B. bigemina and B. argentina; mechanisms of coinfectious immunity; sterile immunity; and the action of chemical compounds tested in this study.

41. KUTTLER, K. L.: Combined Treatment With a Dithiosemicarbazone and Oxytetracycline to Eliminate Anaplasma marginale Infections in Splenectomized Calves. Research in Veterinary Science, (November 1972), 13, (6): 536-539.

A total of 12 treatment schedules combining oxytetracycline and an alpha-dithiosemicarbazone (356C61) were tested on 36 splenectomized calves carrying Anaplasma marginale infections. Anaplasma infection was eliminated following the administration of 5 or 10 mg/kg 356C61 combined with 11 mg/kg oxytetracycline, and given 3 times at 24 or 48 hour intervals. Treatments employing lower levels, fewer injections, or at greater time intervals failed to eliminate infection.

Treated, splenectomized calves failing to show evidence of an A. marginale relapsing infection within 62 days were found to be free of infection on the basis of infectivity trials conducted an average of 87 days after treatment, and by re-inoculation with A. marginale an average of 164 days after treatment.

42. KUTTLER, K. L.: Comparative Response to Premunization Using Attenuated Anaplasma marginale, Virulent A. marginale and A. centrale in Different Age Groups. Tropical Animal Health & Production, (1972), 4: 197-203.

Premunizing infections using virulent Anaplasma marginale (VAM), attenuated A. marginale (AAM) and Anaplasma centrale (AC) have been induced in 46 mature cattle, 33 intact calves, and 38 splenectomized calves, for the purpose of comparing the relative response to these infections.

The VAM produced significantly more severe reactions in adult cattle and splenectomized calves, and a slightly more severe response in intact calves; however, these animals were relatively more resistant to all three infections. There was no detectable difference between the reactions caused by AAM and AC when measured in adult cattle and intact calves. Among splenectomized calves, however, the AAM infections resulted in a milder response as measured by the relative drop in packed cell volume and percent parasitemia. The CF response was significantly lower in the AC infection.

43. KUTTLER, K. L., GRAHAM, O. H., JOHNSON, S. R. and TREVINO, J. L.: Unsuccessful Attempts to Establish Cattle Babesia Infections in White-Tailed Deer (Odocoileus virginianus). Journal of Wildlife Diseases, (January 1972), 8: 63-66.

Attempts to induce a demonstrable cattle Babesia infection by feeding known infected ticks on two white-tailed deer (Odocoileus virginianus) were unsuccessful. The injection of known Babesia carrier blood into an intact and a splenectomized deer failed to result in evidence of infection.

All deer were checked for possible sub-patent infections by inoculating their blood into splenectomized calves at weekly intervals for 5 weeks following exposure, but no infections were produced in the calves.

Babesia infected ticks having undergone one generation on deer were unable to transmit infection to splenectomized calves on the succeeding generation.

44. ARMSTRONG, J. M. and TODOROVIC, R. A.: Anaplasmosis of Cattle. Texas Agricultural Extension Service, A Fact Sheet, No. 10 M-6-73, (1973): 1-4.

A brief description of anaplasmosis, with special emphasis on recent achievements in the field of diagnosis and control was discussed and summarized for Texas A&M University Extension Service publication. This fact sheet was written principally for livestockmen to make them aware of recent developments in the field of anaplasmosis control and action that can be taken for prevention and treatment of this hemotropic disease.

45. BISHOP, J. P. and ADAMS, L. G.: Combination Thin and Thick Blood Films for the Detection of Babesia Parasitemia. American Journal of Veterinary Research, (September 1973), 34, (9): 1213-1214.

A method for preparing and examining combination thin and thick blood films for the detection of Babesia spp. parasitemias was developed. A technique for staining the combination thin and thick films, using a phosphate-buffered Giemsa stain solution containing alkyl phenoxy polyethoxy ethanol (APPE), was also described.



46. BISHOP, J. P., ADAMS, L. G., THOMPSON, K. C. and CORRIER, D. E.: The Isolation, Separation and Preservation of Babesia bigemina. Tropical Animal Health & Production, (May 1973), 5: 141-145.

Experiments were performed in Colombia to separate Babesia bigemina from contaminating organisms. Babesia bigemina was passaged serially through five splenectomized calves. The first calf was inoculated with blood carrying several different organisms, and subsequent subinoculations were done soon after blood smears from each calf were found to be positive for B. bigemina. Five blood passages were carried out in 6.5 days. Babesia argentina, Babesia major and Anaplasma marginale were eliminated as contaminants of the B. bigemina isolated after four passages. A frozen stabulate of the isolated B. bigemina was established.

47. CORRIER, D. E. and ADAMS, L. G.: Observations During Concurrent Anaplasmosis and Babesiosis in Experimentally Infected Calves. Proceedings of the Sixth National Anaplasmosis Conference, Las Vegas, Nevada, (March 1973): 60-65.

The clinical, serological and pathological manifestations of disease in intact calves concurrently infected with Anaplasma marginale and Babesia bigemina were investigated. Clinical signs were more severe in the concurrently infected calves than in singularly infected controls. Decreases in packed cell volume, albumin:globulin ratio, myeloid:erythroid ratio and increases in the number of reticulocytes, total serum proteins and serum gamma globulins were more pronounced in the concurrently infected calves. The concurrent infections had no apparent effect on the production of complement fixing antibodies. Gross lesions observed in the concurrently infected calves included: pleural and peritoneal transudates; splenomegaly; hepatomegaly; and moderate lymph node enlargement. Histological lesions included: moderate hepatocellular degeneration; lymphoid hyperplasia in the spleen and lymph nodes; and hemosiderosis of the spleen, lymph nodes, liver and kidneys. The relationship of A. marginale and B. bigemina during the concurrent infections appeared to be one of independency. The increased severity of the clinical and pathological signs of disease in the concurrently infected calves was attributed to the concurrent infections being additive.

48. CRAIG, T. M.: Infectivity and Cross Immunity Studies of Colombian Bovine Babesia Species. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1973.

Colonies of bovine hemotropic disease free Boophilus microplus ticks were established. Adult B. microplus females and eggs were incubated at 28 to 30° at a relative humidity of from 70 to 80%. Larvae were maintained at 24 to 28° C. and a relative humidity of 60 to 80% for maximal survival.

A colony of B. microplus infected with Babesia argentina was established by allowing non-infected ticks to feed on normal cattle for 10 to 11 days, at which time a stabilate of B. argentina was inoculated into the cattle subcutaneously. This resulted in a parasitemia at the time of final tick engorgement. The organism was maintained in ticks by allowing non-infected ticks to feed on a calf which was later infected by the release of infected larvae 11 to 13 days after the non-infected larvae commenced feeding. Diagnosis of Babesia spp. in ticks was done by examination of hemolymph.

Diagnosis and estimation of the effects of Babesia spp. infections in cattle were made on the basis of thick and thin blood films, packed cell volumes, rectal temperatures, body weights, cerebral biopsies, complement fixation titers and clinical signs.

Boophilus microplus eggs, larvae and nymphs infected with B. argentina were disrupted by several methods and the resulting material inoculated subcutaneously into splenectomized calves. None of the calves showed signs of infection and proved to be fully susceptible when challenged with B. argentina.

Babesia bigemina was isolated from other bovine hemotropic agents by rapid serial passage through splenectomized calves. This isolate was compared with a laboratory strain previously isolated from a different geographic region of Colombia. Two groups of 8 calves each were inoculated subcutaneously with  $10^9$  B. bigemina organisms of each isolate. A third group of 8 calves remained as untreated controls. Twenty-eight days later, 4 calves in each of the 3 groups were challenged with  $2 \times 10^{10}$  B. bigemina organisms of each isolate. The challenge groups were homologous, heterologous and control. Both homologous and heterologous groups demonstrated immunity to challenge. No differences in the virulence of the two isolates were demonstrated.

49. KUTTLER, K. L.: Current Status of the Tropical Cattle Fever Tick Boophilus microplus and Texas Wildlife. Presented to the Wildlife Society, Texas Chapter, Annual Meeting, Barnett, Texas (April 5, 1973), abstract.

The increasing presence of both Boophilus microplus and Boophilus annulatus have created considerable concern among both the Texas livestock industry and those interested in the preservation and maintenance of wildlife. Even though both ticks can complete their life cycles on deer, B. microplus appears better adapted to deer. This tick is very versatile and is capable of maintaining itself on several wildlife species. Neither B. annulatus nor B. microplus are capable of transmitting any known diseases from deer to cattle or from cattle to deer.

Eradication plans have been successful in the past, particularly where B. annulatus was present. The feasibility of B. microplus eradication by similar means was discussed.

50. KUTTLER, K. L.: Review: Current Status of Control and Treatment With Drugs, Proceedings of the Sixth National Anaplasmosis Conference, Las Vegas, Nevada, (March 1973): 93-97.

A review of the literature was given, emphasizing those treatment techniques and reports since the initial use of the tetracyclines for anaplasmosis in 1951. Two new drugs, Imidocarb and Gloxazone, were discussed. These drugs, while more effective than the tetracyclines, have not been cleared by the FDA and remain experimental. At the present time, the tetracyclines are the only effective therapeutic compounds available commercially for the treatment of anaplasmosis. Current recommendations for the elimination of carrier infections are to feed on oral tetracycline for 60 days at the rate of 5 mg/pound of body weight.

51. KUTTLER, K. L. and TODOROVIC, R. A.: Techniques of Premunization for the Control of Anaplasmosis. Proceedings of the Sixth National Anaplasmosis Conference, Las Vegas, Nevada, (March 1973): 106-112.

Attempts at Anaplasma premunization in varying age groups were reported using virulent A. marginale of Texas origin, virulent A. marginale of Colombian origin, attenuated A. marginale and A. centrale. Results of premunization response and response to field and artificial challenge were reported.

Premunization is a practical approach for prevention of clinical losses associated with anaplasmosis, but a series of variables must be considered if success is to be achieved. Some of these factors are: (1) age of animals being premunized, (2) virulence, potency and size of premunizing inoculum, and (3) strain, or size, of expected challenge exposure. In some instances, use of a highly virulent A. marginale in adult cattle resulted in overly severe reactions even with treatment. Gloxazone (356C61) and Imidocard 4A65 were superior to oxytetracycline in moderating the premunizing infection. Attenuated strains of A. marginale when used in young intact calves failed to produce the desired premunizing effect; however, attenuated strains were very effective in adult cattle. Premunization is dependent on establishing an active infection, and in the absence of such infection, susceptibility to field or experimental challenge occurs. Successful premunization resulted in almost complete protection following challenge with antigenically similar A. marginale isolates. Protection was only partial, however, in instances where heterologous challenge was encountered.

52. MAURER, F. D. et al.: Livestock Production and Marketing in Pakistan. A 107 page report to AID based upon a month's survey in August 1973.
53. TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Bovine Babesiosis: Sterile Immunity to Babesia bigemina and Babesia argentina Infections. Tropical Animal Health & Production, (1973), 5: 234-245.

Killed Babesia bigemina and Babesia argentina vaccine was prepared from infected erythrocytes (AG-E) and infected plasma (AG-S) collected from acutely infected calves with B. bigemina and B. argentina. The vaccine was tested in Colombian cattle under field conditions in the Cauca Valley. A total of 40 calves 2-1/2 months of age received killed-Babesia vaccine. Five calves were not vaccinated; they served as controls. Vaccinated and non-vaccinated control calves were exposed to field-borne challenge with Boophilus microplus infected ticks. On the basis of data obtained, it was found that a high degree of sterile immunity to B. bigemina and B. argentina can be produced in calves injected with killed-Babesia vaccine. It appears that sterile immunity plays an important role in the mechanism of acquired immunity to babesiosis, other than well-known co-infectious immunity known as premunition.

54. TODOROVIC, R. A., VIZCAINO, O. G., GONZALEZ, E. F. and ADAMS, L. G.: Chemoprophylaxis (Imidocarb) Against Babesia bigemina and Babesia argentina Infections. American Journal of Veterinary Research, (September 1973), 34, (9): 1153-1161.

The chemoprophylactic effects of imidocarb (3,3'-bis(2-imidazolin-2-yl)-carbanilide dihydrochloride) against bovine babesiosis were evaluated in 29 calves. The compound had prophylactic and therapeutic properties in calves artificially and naturally infected with Babesia bigemina and Babesia argentina of Colombian (South American) origin. Administered intramuscularly at the dose level of 2 mg/kg, imidocarb suppressed development of acute babesiosis in calves treated 46 days previously and later exposed to a lethal dose of Babesia spp.-infected blood. Imidocarb failed to protect against Anaplasma marginale infection. Calves treated intravenously with imidocarb at the dose level 2 mg/kg and challenge inoculated 20 days later with a lethal dose of Babesia spp.-infected blood were protected. For 90 days after challenge, none of the calves had Babesia spp. parasitemia, as determined by examination of stained blood films and by subinoculation of blood into susceptible splenectomized calves. Calves intravenously treated 21 days previously with 3 mg/kg imidocarb resisted tick-borne challenge of Boophilus microplus. This resistance was evidenced for 15 weeks of field exposure by negative results of examinations of stained blood films and death of nontreated calves from acute babesiosis. All calves treated with imidocarb and subsequently exposed to blood or tick-borne Babesia spp. responded with an increase of complement-fixing antibodies.

Imidocarb readily controlled very severe acute infections with B. bigemina and B. argentina when the compound was given at dose rates of 1 mg/kg by both intramuscular or subcutaneous routes. Signs of acute toxicosis were observed in calves given intravenous injections of 3 mg/kg. Three calves died, having signs of embarrassed respiration, oral respiration, excessive salivation, muscular fasciculations, urination, defecation, incoordination, and prostration. Signs of toxicosis were milder with intramuscular or subcutaneous injections of imidocarb.

55. VIZCAINO, O. G. and TODOROVIC, R. A.: Produccion de Antigenos Solubles de Babesia argentina y Babesia bigemina para Pruebas de Immunologia. Proceedings of the VII Panamerican Congresss of Veterinary Medicine and Zootechnics, Bogota, Colombia, (July 23-28, 1973): 38-39, (abstract).

Diagnosis of bovine babesiosis during the acute phase of infection is made by examination of Giemsa-stained blood films; however, during the chronic phase of disease, several serologic tests are used for detection of specific Babesia spp. antibodies. The purpose of the present investigation was to isolate soluble antigens of Babesia bigemina and Babesia argentina from blood acutely infected with these hemotropic parasites and use them in immunodiffusion tests for detection of specific antibodies.

Soluble antigens of B. bigemina and B. argentina were isolated from plasma collected from animals acutely infected with these parasites. By means of column chromatography (DEAE-cellulose and Sephadex-G2000), soluble antigens of B. bigemina and B. argentina were purified from host material and found antigenically specific in gel diffusion tests. Antigenic fractions obtained by above procedures were found to contain protein at 280  $\mu$ w of optical density.

By means of DEAE-cellulose column chromatography, it was possible to separate host hemoglobin from soluble antigens of B. bigemina and B. argentina. Three protein peaks were recorded during fractionation, but only the second peak contained soluble antigens contaminated with host serum proteins. By means of Sephadex-G2000 column chromatography, it was possible to separate normal serum proteins from soluble B. bigemina and B. argentina antigens. When serum samples collected from cattle infected with B. bigemina and B. argentina were subjected to react with soluble antigens in the gel diffusion tests a line of precipitation reaction was observed. Twenty-four or more hours of incubation was necessary for visible reaction.

Specific antibodies to B. bigemina and B. argentina were detected in sera of cattle infected with these parasites for 73 and 83 days of infection in the homologous system tested. An attempt was made to characterize these soluble antigens by means of immunoelectrophoresis. It was found that both antigens migrate a short distance to the positive pole. Antigenic reactivity of B. bigemina and B. argentina soluble antigens was preserved for 6 months at  $-79^{\circ}$  C.

56. ADAMS, L. G.: Epizootia Espontanea de Hepatitis Toxica en Procinos Atribuida a Aflatoxicosis. Revista ICA, (March 1974), 9: 3]-48.

Nine of the 56, 4- to 6-month-old Duroc male and female pigs died 2 months after consuming a ration consisting of 8.75% moldy peanut meal. The pigs exhibited weight loss, roughened hair coats, anorexia, lethargy, icterus, melena, increased followed by decreased rectal temperature and death. The livers of the remaining 45 pigs were condemned due to cirrhosis. Serum sorbitol dehydrogenase activities, glutamic-oxaloacetic transaminase activities, bilirubin concentrations, serum beta globulin levels, serum gamma globulin levels, and total serum protein concentrations were increased as serum albumin/globulin ratios, albumin levels, packed cell volume and hemoglobin contents were decreased. No changes were observed in total leukocyte counts or serum alpha globulin levels.

The principal macroscopic lesions consisted of generalized icterus, petechial and ecchymotic hemorrhages with yellow transudates occurring in the body cavities. Subendocardial as well as subserosal ecchymotic hemorrhage were commonly observed. Ulceration of the gastric fundus occurred which filled the stomach, duodenum, jejunum, ileum, and colon with free digested and undigested blood. The liver was pale yellowish-brown, firm (increased cutting resistance), and cirrhotic with very accentuated hepatic lobules outlined by translucent bands. Hundreds of irregular round yellow to brown foci of hepatic nodular regeneration were interspersed throughout the hepatic parenchyma. The gall bladder was moderately edematous and contained a small amount of light green bile. The principal microscopic lesions of the liver were disorganization of the hepatic architecture, acinus formation, severe sinusoidal fibrosis, mild biliary hyperplasia, advanced hepatic nodular regeneration, extensive hepatocellular megalocytosis, hepatocellular anisocytosis, mild hepatocellular necrosis, fatty metamorphosis, and moderate cholangiolar bile plug formation. The diagnosis and etiology of these 4 cases of porcine chronic toxic hepatitis was attributed to aflatoxicosis apparently produced by Aspergillus flavus growing on peanut meal. The present article is the first report of aflatoxicosis in Colombia.

57. ADAMS, L. G. and TODOROVIC, R. A.: The Chemotherapeutic Efficacy of Imidocarb Dihydrochloride on Concurrent Bovine Anaplasmosis and Babesiosis. I. The Effects of a Single Treatment. Tropical Animal Health & Production, (1974), 6: 7]-78.

The chemotherapeutic efficacy of imidocarb dihydrochloride (3,3'-bis(2-imidazolyl)carbanilide dihydrochloride) administered as single intramuscular doses of 1.0, 2.0, and 2.5 mg/kg, against concurrent bovine anaplasmosis and babesiosis, is reported. Dosages of 2.0 and 2.5 mg/kg of imidocarb dihydrochloride rapidly inhibited acute ascending concurrent parasitaemias of Anaplasma marginale, Babesia bigemina and Babesia argentina; however, 1.0 mg/kg had a minimal effect on A. marginale, but was very effective against B. bigemina and B. argentina. Imidocarb dihydrochloride at 1.0, 2.0 and 2.5 mg/kg inhibited the development of immunity of the acute Babesia spp. infections, making the calves more susceptible to babesiosis upon challenge.

58. ADAMS, L. G. and TODOROVIC, R. A.: The Chemotherapeutic Efficacy of Imidocarb Dihydrochloride on Concurrent Bovine Anaplasmosis and Babesiosis, II. The Effects of Multiple Treatments. *Tropical Animal Health & Production*, (1974), 6: 79-84.

Intact Anaplasma marginale, Babesia bigemina and Babesia argentina carrier calves treated intramuscularly 5 or 10 times with 2.5 mg/kg of imidocarb dihydrochloride at 48-hour intervals eliminated the Babesia infections, but not Anaplasma infections. The parasitemias became microscopically undemonstrable within 4 days following the first treatment, and the packed cell volumes increased significantly within 18 days. Intoxications resulting in fatalities occurred in 5 of 6 calves given 10 intramuscular treatments of 2.5 mg/kg of imidocarb dihydrochloride at 48-hour intervals.

59. ALIU, Y. O.: Absorption, Distribution, and Excretion of Imidocarb Dipropionate [3,3'-bis-(2-imidazolin-2yl)carbanilide] in Sheep. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, August, 1974.

Spectrophotometric and thin-layer chromatographic methods for quantitative and qualitative determination of Imidocarb in biologic specimens are described. Imidocarb was extracted under basic conditions from plasma, urine, milk, bile, and homogenized tissue samples in organic solvents. Following extraction and concentration in 0.82 N HCL, the drug was quantitatively identified by spectrophotometry. The limits of accuracy are estimated to be 1.0 µg/ml in plasma and other body fluids and 5.0 µg/gm in tissues.

High plasma levels were reached in 4 hours after the intramuscular injection of 4.5 mg/kg Imidocarb. This was followed by rapid decline initially but later the rate of decline was reduced so that trace amounts were still present weeks after the injection. High and persistent tissue residues were characteristic of this drug. Approximately 11-17% of the administered drug was excreted in the urine within 24 hours, but thereafter the excretion rate was low. The relatively high concentrations of the drug found in the bile suggest that biliary excretion is an important route of drug elimination. High concentrations were found in the milk of lactating ewes. When the milk was fed to nursing lambs, no drug could be detected in their plasma.



60. BISHOP, J. P. and ADAMS, L. G.: Babesia bigemina: Immune Response of Cattle Inoculated with Irradiated Parasites. Experimental Parasitology, (1974), 35: 35-43.

Effects of various radiation dosages on the infectivity and immunogenicity of Babesia bigemina were studied. Calves infected with  $1 \times 10^{10}$  B. bigemina parasitized erythrocytes exposed to 24 krad developed progressive parasitemias. Some calves receiving  $1 \times 10^{10}$  parasitized erythrocytes irradiated at 36 krad did not develop progressive infections. Progressive infections were prevented by exposure to irradiation at 48 and 60 krad. A degree of acquired resistance to infection with B. bigemina developed in calves after inoculation with parasites irradiated at 48 and 60 krad. The resistance developed was sufficient to suppress multiplication of the Babesia and to permit calves to survive otherwise severe clinical infections due to challenge with nonirradiated parasites. Irradiated parasites were frozen without apparent loss of immunizing properties.

61. BISHOP, J. P. and KUTTLER, K. L.: Infectivity and Immunogenicity of Irradiated Babesia rodhaini. Journal of Protozoology, (1974), 21, (5): 758-760.

Babesia rodhaini parasitized mouse blood exposed to varied doses of gamma radiation up to 30,000 r was inoculated into mice. Mice inoculated with nonirradiated B. rodhaini developed progressive infections and died 7 to 11 days after inoculation. Mice infected with B. rodhaini parasitized blood exposed to doses up to and including 22,000 r developed progressive parasitemias which were delayed in comparison to mice inoculated with nonirradiated B. rodhaini. Some mice receiving parasitized blood irradiated at 26,000 r did not develop progressive parasitemias. Progressive infections were prevented by exposure to irradiation at 30,000 r.

The results of two separate experiments revealed that one inoculation of parasitized blood exposed to 30,000 r or higher apparently stimulated a resistance to a challenge infection with nonirradiated parasitized blood. While 20 out of 20 control mice died as a result of challenging infections, 9 out of 28 mice previously exposed to irradiated parasitized blood survived.

The injection of irradiated nonparasitized blood did not produce a discernable acquired resistance to B. rodhaini. Presumably the irradiated parasitized blood was responsible for the development of acquired resistance to B. rodhaini.

62. CORRIER, D. E.: A Clinical, Histological and Ultrastructural Study of the Toxic Effects of Imidocarb Dipropionate in Goats. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, August 1974.

The toxic effects of imidocarb dipropionate were studied in adult goats following the intramuscular injection of a lethal dosage of the drug. The acute clinical signs of toxicosis were transient and included excessive salivation, diarrhea, dyspnea, anorexia and inactivity. Significant increases in the mean serum urea nitrogen concentrations, serum glutamic oxaloacetic transaminase activities, and absolute neutrophilic leukocytes occurred.

The most prominent gross pathological lesions were enlarged, pale kidneys with the presence of alternating red and white streaks in the renal cortex, hydrothorax, hydropericardium, ascites, and pulmonary edema. The histological alterations included severe acute tubular necrosis of the proximal convoluted tubules of the renal cortex beginning as early as 6 to 12 hours post-injection and massive pulmonary edema.

Ultrastructural lesions were observed at 3 hours and progressed rapidly in the next 24 hours to include disruption of plasma membranes, dilation and proliferation of the endoplasmic reticulum, swollen electron dense mitochondria, and rarefaction of the cytoplasmic ground substance. Finally, complete disruption of the plasma membrane with fragmentation of the microvilli, loss of junctional complexes and cellular disjunction became evident from 12 to 24 hours post-injection.

Progressive decreases were observed in succinic dehydrogenase and adenosine triphosphatase activities beginning at 12 hours and 24 hours post-injection, respectively. The loss of ability of the epithelial cells of the proximal convoluted tubules to regulate cell volume was considered to have been the initial event responsible for the subsequent ultrastructural, histological and histochemical changes observed following the injection of imidocarb dipropionate.

63. KUTTLER, K. L.: Chemotherapy and Eradication of Anaplasmosis. Proceedings of the Third International Congress of Parasitology, Munich, Germany, (August 25-31, 1974), 3: 1308-1309, (abstract).

Methods of anaplasmosis eradication have been described, based on the principle of identifying carrier or infected cattle and the removal of this infection. Infection may be eliminated by segregation, slaughter, or segregation and treatment. The latter method is still handicapped by the relatively expensive procedures involved with long-term feeding of tetracyclines. Tests of new and experimental drugs show that improved techniques are more practical in terms of the number of treatments necessary for the elimination of Anaplasma infection.

Both Imidocarb [3,3'-bis-(2-imidazolyl)carbanilide dihydrochloride/dipropionate] and Gloxazone [alpha-ethoxyethylglyoxal dithiosemicarbazone] (Burroughs Wellcome Company, Inc. - Research Triangle Park, North Carolina) have been shown to be therapeutically active against Anaplasma. Imidocarb has effectively eliminated Anaplasma infection when administered 3 times at 24 to 48 hour intervals, using 4, 5, 6 mg/kg, or giving 5 mg/kg twice at a 2-week interval. Gloxazone, while therapeutically effective against Anaplasma, will not eliminate the infection in sub-toxic levels. Anaplasma infection can be eliminated with reduced amounts of Gloxazone when it is combined with oxytetracycline. The combination of Gloxazone and Imidocarb has been shown successful in eliminating infection with as little as 1 mg/kg Gloxazone and 3 mg/kg Imidocarb, when each compound is given twice at a 2-week interval.

Anaplasmosis is endemic in much of the intermountain west and Pacific west coast. The principle vectors there are ticks, and deer are known to act as a reservoir of infection. It is doubtful if eradication of Anaplasma under these circumstances is practical or even possible with present-day techniques.

There are large areas in Africa and South America where ticks are the principle Anaplasma vectors, where non-bovine reservoirs probably exist which would pose a similar problem. Chemotherapy under these conditions can best be used for control rather than eradication. All 3 compounds used in reduced amounts are effective in reducing the severity of infection, allowing the animals to become carriers of infection, hence immune to further reinfection.

64. MAURER, F. D.: Obtaining Support for Research on Animal Health. Journal of the American Veterinary Medical Association, (July 15, 1974), 165, (2): 196-197.

The principle source of funds for research in the colleges of veterinary medicine has long been from agencies of the Federal government. In general, Federal agencies have placed emphasis upon human health related problems even though experimental animals and veterinarians were involved. As a result, there has been a relative neglect of those diseases of livestock which reduce U.S. production by 11 to 15% per year.

Rather than for the livestock industry to wait for government assistance, it is urged that livestock associations support research toward the solution of their own problems. Other industries find it economically profitable to plow back some 15% of annual profits into research and development; this could apply to livestock as well.

65. MAURER, F. D.: African Agricultural Research Capabilities. National Academy of Sciences, Washington, DC, 1974. A publication of 221 pages.

The work of an international committee, of which F. D. Maurer was the veterinary member, compiled this report which constitutes a review of the needs, opportunities, facilities and personnel for research on the major agricultural crops and livestock. Emphasis is upon research required to solve major problems which now handicap crops and livestock production. Our primary area of concern was for research on animal disease problems. The committee's work was financed by USAID.

66. MILLER, R. M.: Investigations on Transstadial Transmission of Bovine Anaplasmosis and Benign Bovine Theileriosis in Cattle by Two Species of Amblyomma (Acarina : Ixodidae). A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, August 1974.

Nymphal stages of both Amblyomma americanum (Linnaeus) and A. cajennense (Fabricius) engorged either on a holstein bull calf chronically infected with Anaplasma marginale (Theiler), or on a holstein bull calf chronically infected with a Theileria organism resembling Theileria mutans (Theiler). After natural detachment and molting, the exposed adult ticks subsequently engorged on non-infected splenectomized holstein bull calves.

During engorgement of exposed adult ticks and for 75 days after their natural detachment, the splenectomized calves were monitored for the presence of blood parasites using both complement-fixation tests and Giemsa-stained thin blood smears. No evidence of infection was observed. After 90 days, the splenectomized calves were challenged to see if they were actually susceptible to either of the two blood parasites. Inoculations of blood demonstrating a parasitemia of either A. marginale or the Theileria were administered to the splenectomized calves which had been previously exposed to the test group of adult ticks. The splenectomized calves developed evidence of both anaplasmosis and theileriosis, suggesting they were susceptible to the blood parasites at the time of tick infestation.

67. PLATT, K. B.: The Development of an Indirect Fluorescent Antibody Test for Trypanosoma vivax in Colombia. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of master of Science, May 1974.

An indirect fluorescent antibody (IFA) test for Trypanosoma vivax infections was developed for a survey involving over 2,000 cattle distributed throughout 11 departments and territories in Colombia. The antigen for the IFA test was prepared from the blood of infected calves by making thin blood smears that were air-dried and fixed in acetone:methanol: 60:40 at -20° C for 30 minutes. The antigen prepared in this manner was useful up to and including 144 days when stored at -70° C. IFA test serum titers of 1:100 or greater were considered to be positive. No cross-reactivity of the IFA test was observed between T. vivax and Anaplasma marginale, Babesia argentina, Babesia bigemina, Eperythrozoon sp. or Trypanosoma theileri at 1:50 serum dilutions. Suspicious reactions occasionally were observed when Trypanosoma evansi positive serum was diluted 1:50 and 1:100 and used in the IFA test for T. vivax. The IFA test could be repeated within plus or minus one serum dilution approximately 80% of the time using different antigen lots on the same and different days. Samples obtained for the IFA test by eluting serum from dried impregnated filter paper discs produced results nearly equal to those obtained by using conventional serum samples. The IFA test was up to 20 times more effective in detecting T. vivax positive cattle than the thick blood smear technique. The IFA test demonstrated the presence of T. vivax antibodies in cattle from 5 departments in Colombia, while antibodies were not detected in the serum of cattle from 6 other departments of Colombia.

68. THOMPSON, K. C.: A Comparison of the Antigenic Properties of Erythrocytic Babesia bigemina in Acute and Chronic Blood Borne and Tick Borne Infections in Cattle. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, May 1974.

This study was made to determine possible antigenic differences in a Babesia bigemina isolate in acute and chronic blood borne and tick borne infections of cattle.

On the basis of the serological results, antigenic variation within an isolate of B. bigemina occurred. Antigenic variation appeared to be influenced by the mode and duration of infection. The hosts' apparent reduced response to homologous challenge and the marked response observed with heterologous systems indicated antigenic differences of B. bigemina.

69. TODOROVIC, R. A.: Bovine Babesiosis: Its Diagnosis and Control. American Journal of Veterinary Research, (August 1974), 35, (8): 1045-1052.

The investigation was conducted to develop new systems and to evaluate existing ones for diagnosis and control of bovine babesiosis in Colombia, South America. Antigens of Babesia bigemina and Babesia argentina were isolated and were used in complement-fixation (CF) and rapid agglutination (RA) tests for the diagnosis of babesiosis in calves.

Three systems were evaluated for control of bovine babesiosis: (1) vaccination of calves with killed Babesia spp. vaccine to produce resistance (based on sterile immunity), (2) premunition of calves with virulent Babesia spp. and then administration of a chemotherapeutic drug to produce resistance (based on coinfectious immunity), and (3) chemoprophylaxis, using a babesiacide having long residual activity. The 3 systems controlled bovine babesiosis under the conditions of the present experiments.

Epizootiologic conditions in enzootic areas, however, will indicate which system is preferable. In zones having a high population of the tick Boophilus microplus, premunition (system 2) is indicated; in areas where the tick population is controlled or in areas where cattle are at constant risk of tick exposure, vaccination with killed Babesia spp. (system 1) or chemoprophylaxis (system 3) are indicated.

70. TODOROVIC, R. A.: Prevention and Control of Bovine Anaplasmosis and Babesiosis (Piroplasmiasis). Proceedings of the Texas Animal Production Conference for Latin American Cattle Producers, College Station, Texas, (January 21, 1974), abstract.

The purpose of this report was to discuss the epizootiological similarities between anaplasmosis and babesiosis, and to emphasize recent developments concerned with prevention and control. In addition, the mechanism of immunity of these hemotropic diseases was discussed.

71. TODOROVIC, R. A. and KUTTLER, K. L.: A Babesiasis Card Agglutination Test. American Journal of Veterinary Research, (October 1974), 35, (10): 1347-1350.

A babesiasis card agglutination test (BCT) has been developed for detecting specific antibodies in cattle infected with Babesia bigemina. The agglutinating antigen was isolated from the blood of a splenectomized calf having 22% B. bigemina parasitemia. The antigen was preserved with 0.02% formalin and stained with fast green dye. The BCT was performed by adding 1 drop of antigen and 2 drops of plasma or serum on a card and mixing for 5 minutes by rotation. Agglutination was visible in instances of positive reactions immediately after rotation.

In cattle intentionally exposed to B. bigemina, the BCT detected agglutinating antibodies simultaneously with the onset of first parasitemia. This reaction was observed to persist as long as 3 months, or long after the disappearance of parasitemia. Because of its simplicity and apparent specificity, the BCT may have use as a field test to aid in the diagnosis of B. bigemina infections. The BCT results showed 100% agreement with the complement-fixation (CF) test on those serums prepared from blood collected within 3 months of infection.

72. VIZCAINO, O. G. and TODOROVIC, R. A.: Inmunidad Cruzada en Bovinos Portadores de Babesia argentina y Babesia bigemina. Proceedings of the IX Congreso Nacional de Medicina Veterinaria y Zootecnia, Barranquilla, Colombia, (July 24-28, 1974).



73. ADAMS, L. G., CRAIG, T. M., PLATT, K. B. and WYSS, J. H.: Bovine Eperythrozoonosis in Colombia. Revista ICA, (December 1975).

Eperythrozoon wenyoni, Eperythrozoon tejanodes and Eperythrozoon tuomii were diagnosed in 14 of 37 splenectomized, Holstein-Friesian, 4-to-11-month-old calves that originated from the Sabana de Bogota. Eleven calves had pure infections of E. wenyoni, 2 calves had dual infections of E. wenyoni and E. tejanodes, and 1 calf had a pure infection of E. tuomii. The diagnosis was determined on Giemsa-stained blood smears, and morphological descriptions of the Eperythrozoon spp. were given. Six splenectomized calves exhibited depression and anorexia, but all 14 calves had elevated rectal temperatures. Two calves had serous conjunctivitis with excessive lacrimation. The increase in rectal temperature coincided with the onset of parasitemia while the packed cell volume decreased after the onset of parasitemia. The average incubation period and standard deviation was  $14.9 \pm 3.5$  days post-splenectomy. Treatment with 2-di-(Beta, gamma-dioxipropil)-(aminofenol)-(4 arseno 5)-Beta-(benzaxozalil)-(2)-mercaptol-propionato de sodio at 29 mg/kg intramuscularly caused the parasitemia to become undemonstrable within 24 hours with further recrudescence occurring within 6 weeks.

This is the first report of bovine eperythrozoonosis due to E. wenyoni, E. tejanodes and E. tuomii in Colombia.

74. CORRIER, D. E.: The Epidemiology of Bovine Anaplasmosis and Babesiosis in the Lowland Tropics of Colombia. Proceedings of the Seminario Sobre Hemoparasitos (Anaplasmosis y Babesiosis), CIAT, Cali, Colombia, (March 17-22, 1975).

The prevalence of anaplasmosis and babesiosis was determined on 37 ranches in the Eastern plains, 4 ranches on the Atlantic coast, and on 6 ranches in the Cauca Valley of Colombia. A random group of cattle representing a minimum of 10% of the total herd were sampled on each ranch ensuring that animals less than 1 year, 1 to 2 years and more than 2 years of age were included in the sample group. A total of 3,698 serum samples were collected and tested using the complement fixation test. Tick counts were made and ticks were collected for classification on each of the 37 ranches visited in the Eastern plains.

The prevalence of Anaplasma reactors was determined to be 75% in the Eastern plains, 91% on the Atlantic coast and 71% in the Cauca Valley. The prevalence and even distribution of Anaplasma reactors among the 37 ranches in the Eastern plains indicated anaplasmosis is endemic within the entire study area. The prevalence of Anaplasma reactors on the 4 ranches on the Atlantic coast, and the 6 ranches in the Cauca Valley, though based on inadequate sample sizes for the areas in general, suggests that anaplasmosis is probably endemic in both areas.

The prevalence of Babesia bigemina reactors was determined to be 42% in the Eastern plains, 77% on the Atlantic coast and 75% in the Cauca Valley. The prevalence of infection with B. bigemina in the Eastern plains indicated the area is endemic. However, the percentage of reactors among the 37 ranches varied from 5 to 98%, which indicated the disease is not evenly distributed through out the area. The prevalence of B. bigemina reactors on the Atlantic coast and in the Cauca Valley suggests that babesiosis is probably endemic in both areas.

The high prevalence of anaplasmosis and babesiosis within the 3 areas in which the study was conducted indicates the importance of exposing calves to infection at an early age when maternal antibodies and natural resistance provide maximum protection against clinical disease.

The necessity of providing protection through immunization or other procedures to susceptible cattle which may be transferred into the areas was strongly indicated.

Boophilus microplus ticks were indentified on each of the 37 ranches in the Eastern plains and were nearly equally distributed as indicated by nonsignificant differences in the tick counts. Ticks identified as Amblyomma cajennense, Amblyomma triste and Anocentor nitens were collected on 3 of the ranches indicating that their role as vectors or potential vectors of anaplasmosis and/or babesiosis is limited.

75. CRAIG, T. M.: The Prevalence of Bovine Parasites in Various Environments Within the Lowland Tropical Country of Guyana. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, December 1975.

The variety and relative abundance of bovine hemo, external and helminth parasites were compared between four ecologically distinct areas of Guyana. The coastal area, the richest agricultural area within the country, contains the highest livestock populations. The cattle for the most part are secondary to crop production on the alluvial soils reclaimed from mangrove swamps. The forested areas of Guyana are a true rain-forest with a four layer tree canopy. Livestock production is being developed in areas cleared of forests. The mid-savannahs area natural brown sand savannahs dominated by Trachypogon plumosus. This grass is unpalatable to cattle for much of the year. The Rupununi is a large savannah with an 8 month dry period. The dominant grass in this savannah is also T. plumosus.

The following hemoparasites were identified: Trypanosoma vivax in 0.7% of the coastal cattle; Anaplasma marginale in 85% of the cattle with the highest prevalence in the mid-savannahs and the lowest on the coast; the serological prevalence of Babesia bigemina was 31% and Babesia argentina 11% with a lower prevalence in the forested areas.

The tropical cattle tick, Boophilus microplus, was found in all areas of the country except at the village of Aishalton in the Rupununi. Other species of ticks found parasitizing cattle or in the vicinity of cattle populations were Amblyomma cajennense, Amblyomma triste and Anocentor nitens.

Insects identified parasitizing cattle were Haematopinus quadripertusus on the coast, Dermatobia hominis, Cochliomyia hominivorax and Haematobia irritans in the mid-savannahs; and Simulium haematopotum in the Rupununi.

The following helminth parasites were identified in Guyana: an apparently undescribed species of Ostertagia from the coast; Haemonchus placei and Haemonchus similis on the coast; H. similis in the Rupununi; Trichostrongylus axei, Cooperia punctata, Bunostomum phlebotomum, Strongyloides papillois, Toxocara vitulorum, Capillaria bovis, Oesophagostomum radiatum, Trichuris discolor, Dictyocaulus viviparus, Mammomonogamus laryngeus, Onchocerca lienalis, Setaria labiatopapillosa, Stephanofilaria stilesi, Moniezia sp. and Cotylophoron cotylophorum.

Parasite profiles compared the coast and Rupununi helminth fauna. Bioclimatographs for the various regions of the country were prepared considering some of the more important genera of helminths and B. microplus. Fasciola and Cysticercus, two helminths expected to be encountered in a country like Guyana, were not found.

This study evaluates the factors concerned with the variety and abundance of various parasites considering edaphic, climatic, botanic, zoologic and social conditions which may be involved in their distribution. It was essential to determine what parasites are likely to be of economic importance, and what practices may be used to control these parasites.

76. DAY, W. C. and KUTTLER, K. L.: Animal Health Considerations Involved in the Movement of U.S. Cattle to Haiti. *Southwestern Veterinarian*, (1975), 28, (3): 229-232.

A total of 44 young Charolais cattle were moved from Texas to Haiti. They were vaccinated against anaplasmosis (1 injection only), anthrax and shipping fever. They were treated with 2,8 mg/kg body weight of Imidocarb before being exposed to infected Boophilus ticks.

Based on serologic evidence, infections with Anaplasma occurred over 90% of the calves within the first 130 days. Babesia infections apparently occurred in over 70% of the calves within this same period of time. No deaths, however, occurred during the first 130 days.

77. GONZALES, E. F. and TODOROVIC, R. A.: Evaluacion de la Inmunidad Coinfecciosa y Esteril en el Control de la Babesiosis Bovina. Proceedings of the II Congreso Latinoamericano de Buiatria, Sesion III. Enfermedades Transmisibles y por Hematozoarios, Maracaibo, Venezuela, (February 23-28, 1975).
78. GUZMAN, V. H., ADAMS, L. G. and GALVIN, T. J.: Verminosis Larinea Bovina Produciada por Mammomonogamus laryngeus en Colombia. *Revista ICA*, (June 1975).

Eight cases of bovine laryngeal verminosis were diagnosed in Valle del Cauca, Colombia, and confirmed by parasitological studies. Macroscopic and microscopic descriptions were made of the lesions caused by Mammomonogamus laryngeus.

79. KUTTLER, K. L.: Diagnosis of Anaplasmosis: A Review. Proceedings of the Seminario Sobre Hemoparasitos (Anaplasmosis y Babesiosis), CIAT, Cali, Colombia, (March 17-22, 1975). CIAT Series CE-12, 93-103.

Reliable tests are available to diagnose both acute and chronic anaplasmosis. A high degree of correlation and agreement occurs between the complement-fixation (CF) and the capillary tube agglutination test, and between the CF and the rapid card test (CT). Both the CF and CT are recognized as official tests for interstate movement of cattle where regulations require a preshipment negative test.

80. KUTTLER, K. L.: Hemoparasites as They Influence Native-Born and Introduced Cattle in the Tropics. Proceedings of the Continuing Education Programme in Animal Production and Health - Beef Cattle, Malaysia, (August 18-22, 1975).

The arthropod-borne, hemoparasitic diseases (anaplasmosis, babesiosis, theileriosis, and trypanosomiasis) occur throughout the world, but more intensely in tropical and subtropical zones where adequate vectors are present to maintain and transmit the disease agent. Control programs are discussed. The selection of the best system for use in Malaysia will have to be determined by research and by evaluating each system under local conditions. Malaysia is fortunate in not having areas infected with virulent Theileria or Trypanosoma, since these conditions would probably survive and produce cattle losses if introduced. Extreme caution is recommended in the importation of cattle.

81. KUTTLER, K. L.: Use of Imidocarb to Control Anaplasmosis. Southwestern Veterinarian, (1975), 28, (1): 47-52.

A field trial was conducted on 469 cattle to determine the effectiveness of imidocarb [3,3'-Bis-(2-imidazolin-2-yl)-carbanilide dipropionate] which was injected intramuscularly 2 times 14 days apart at a level of 5 mg/kg body weight. Treatment was therapeutically effective, but these methods failed to produce the desired control. An initial drop in positive serum response as measured by the complement-fixation test was noted after treatment. This was followed by a gradual increase, thought to be due to reinfection. One year after treatment the rate of positive serum tests was essentially the same as before treatment.

Even though effective drugs are available to treat anaplasmosis, caution is indicated in those herds in which the infection rate is high and transmission is active.

82. KUTTLER, K. L. and CRAIG, T. M.: Isolation of a Bovine Theileria. American Journal of Veterinary Research, (March 1975), 36, (3): 323-325.

Dual infections of Anaplasma marginale and a Theileria, resembling Theileria mutans, occurred in splenectomized calves inoculated with pooled blood samples from eastern Texas cattle. Theileria was obtained in pure form by treating dually infected cattle with gloxazone and imidocarb which selectively eliminated Anaplasma. These Theileria infections were responsible for mild, transient reductions in packed red blood cell volume.

83. KUTTLER, K. L., GRAHAM, O.H. and TREVINO, J. L.: The Effect of Imidocarb Treatment on Babesia in the Bovine and the Tick (Boophilus microplus). Research in Veterinary Science, (1975), 18: 198-200.

Treatment of calves with 5 mg/kg Imidocarb [3,3'-bis-(2-imidazolin-2-yl)carbanilide dipropionate] given intramuscularly 14 days before and 14 days after exposure to Babesia infected Boophilus microplus larvae rendered the next generation of larvae incapable of transmitting Babesia infection. When administered to calves 14 or 28 days before tick exposure, the drug prevented the development of clinical babesiosis; the larval progeny of ticks reared on the calf which was treated 28 days before infestation were infective. Treatment of a calf 42 days before exposure to infective larvae did not prevent the development of a Babesia parasitemia but appeared to reduce the severity of infection.

84. KUTTLER, K. L. and ZARAZA, H.: Evaluacion Preliminar del Dithiosemicarbazone para el Tratamiento de la Anaplasmosis. Revista ICA, (June 1975).
85. MAURER, F. D.: African Swine Fever. A 16 page chapter in the 4th edition of Diseases of Swine, a textbook by H. W. Dunne and A. D. Leman, 1975.

This is a comprehensive detailed review of African Swine Fever as the most serious single disease threat to the world's swine industries. Sections cover history and distribution of ASF, the etiology with details about the virus, and its characteristics as an antigen, the host range, transmission, clinical character of the disease, the gross and microscopic pathology with considerable illustrated detail of the histopathology, with emphasis on features most important to the diagnosis. The serologic diagnosis has become increasingly important in view of the increased pathologic similarity of chronic ASF to hog cholera, as ASF now appears in Spain.

86. MAURER, F. D.: Livestock, a World Food Resource Threatened by Disease. Journal of the American Veterinary Medical Association, (May 1, 1975), 166. (9): 920-923.

This is an editorial-type article which stresses the essential role of livestock as a world food resource and the importance of disease control for efficient livestock production, hence, man's food supply.

87. MAURER, F. D.: The Work of the Institute of Tropical Veterinary Medicine, Texas A&M University. Proceedings of the Seminario Sobre Hemoparasitos (Anaplasmosis y Babesiosis), CIAT, Cali, Colombia, (March 17-22, 1975).

This report outlines the Institute's origin, purpose, objectives, and research.

88. REYNOLDS, S. D.: Evaluation of Methods of Premunition to Anaplasma marginale. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, May 1975.

Twenty-one yearling, crossbred, beef heifers were divided into 3 experimental groups and premunized by inoculating intravenously 2 ml of a  $10^{-2}$  dilution of an Anaplasma stabilate of Texas origin. A similar group of 4 heifers was maintained as non-infected controls.

Seven cattle in group I were vaccinated with "Anaplaz" 2 times, at a 4-week interval, prior to the premunizing infections. Nine cattle in group II were premunized and allowed to go untreated during the course of infection. Five cattle in group III were each treated with 11 mg/kg oxytetracycline intravenously when the Anaplasma parasitemia was about 4.6%.

Complement-fixation (CF) titers preceded the appearance of an Anaplasma parasitemia by up to a week. Clinical manifestations associated with Anaplasma parasitemia were mild in all groups and limited to rough haircoat, an unthrifty appearance and a slight loss of weight. The infection in all groups was characterized by lower packed cell volume (PCV), reduced red cell counts, low hemoglobin and increases in the mean corpuscular volume when compared to the controls; however, no significant group differences in these parameters were detected. Cattle of group I showed slightly longer incubation times and higher CF titers than cattle in groups II and III. The recovery rates for cattle in groups I, II and III showed no significant differences.

A challenge consisting of 5 ml whole, fresh blood from a splenectomized calf showing an 8% Anaplasma parasitemia and a 20% PCV was administered intravenously to all 25 experimental cattle after the premunizing infection had subsided. This challenge was calculated to represent over 100,000 times more infectious particles than the premunizing infection. Premunized animals were solidly immune to challenge, whereas the controls were severely affected.

89. TODOROVIC, R. A.: Babesiosis. Proceedings of the XX World Veterinary Congress, Symposium on Immunology of Animal Diseases Caused by Blood Protista, Thessaloniki, Greece, (July 6-12, 1975): 269-270.
90. TODOROVIC, R. A.: Non-Chemical Control of Blood Parasites. Proceedings of the XX World Veterinary Congress, Section on Parasitology, Thessaloniki, Greece, (July 6-12, 1975): 222-223.
91. TODOROVIC, R. A.: Serological Diagnosis of Babesiosis: A Review. Tropical Animal Health & Production, (1975), 7: 1-14.

In the last three decades some fundamental knowledge concerning the immunoserology of Babesia spp. infections has led to the development of serological techniques which provide a means for studying the pathogenesis of babesiosis and the detection of animals with subclinical infections.

The antigens used in the serological procedures originated from the parasitized erythrocytes, plasma, and tissues of animals with acute babesiosis. Parasitic and serum soluble antigens were applied in a variety of serological tests, e.g., complement fixation, gel precipitation, agglutination, and fluorescent antibody, for detection of Babesia spp. antibodies.

In this review an attempt was made to summarise and discuss the recent advances in the serodiagnosis of babesiosis, together with conditions where the use of serological methods may be valuable.

92. TODOROVIC, R. A. and GONZALEZ, E. F.: Avances Recientes en el Sero-diagnostico de Babesiosis Bovina. Proceedings of the II Congreso Latinoamericano de Buiatria, Sesion III. Enfermedades Transmisibles y por Hematozoarios, Maracaibo, Venezuela, (February 23-28, 1975).
93. TODOROVIC, R. A. and GONZALEZ, E. F.: Evaluacion de la "Premunicion" Para el Control de Anaplasmosis y Babesiosis en Fincas Comerciales del Valle del Cauca (Colombia). Proceedings of the Seminario Sobre Hemoparasitos (Anaplasmosis y Babesiosis), CIAT, Cali, Colombia, (March 17-22, 1975).



94. TODOROVIC, R. A. and GONZALEZ, E. F.: Inmunizacion contra Babesiosis Bovina con Vacuna a Base de Parasitos Muertos. Revista ICA, (March 1975), 10: 87-99..

Non-living Babesia bigemina and Babesia argentina antigens were prepared from infected erythrocytes and from plasma collected from acutely infected calves. The antigens were lyophilized and stored at -20° C. The preparations were tested in Colombian cattle under field conditions in the Cauca Valley.

A total of 16 calves distributed in 4 groups of 4 calves each were injected and 4 calves not injected were used as controls. Calves (Group A) were injected with lyophilized plasma only; calves (Group B) were injected with lyophilized plasma plus adjuvant; calves (Group C) were injected with lyophilized parasitized erythrocytes only; and calves (Group D) were injected with lyophilized parasitized erythrocytes plus adjuvant. The inoculations were given twice at 2-week intervals. Vaccinated and non-vaccinated calves were exposed to field challenge with Boophilus microplus infected ticks. Immunological response was measured by packed cell volume (PCV), parasitemia (P), complement fixation test (CF), body weights and mortality.

It was found that a high degree of sterile immunity to B. bigemina and B. argentina can be produced in susceptible calves by injecting them with non-living Babesia spp. antigens.

95. TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Babesia bigemina, Babesia argentina, and Anaplasma marginale: Coinfectious Immunity in Bovines. Experimental Parasitology, (1975), 37: 179-192.

Forty-eight intact and 8 splenectomized cattle were used to evaluate different systems of coinfectious immunization against Babesia bigemina, Babesia argentina, and Anaplasma marginale. Coinfectious immunity was induced by 2 methods: (1) blood of cattle acutely infected with B. bigemina, B. argentina and A. marginale was used as the source of inoculum and the post vaccination reactions were chemotherapeutically controlled with Imidocarb, Ganaseg, Gloxazone, and Liquamycin, and (2) by artificially inducing babesiosis with the blood of carrier cattle with chronic infections of B. bigemina and B. argentina without chemotherapy. The degree of resistance was determined by blood-borne and tick-borne challenges. Ticks were collected from cattle and identified as Boophilus microplus and Dermacentor nitens. Vaccinated cattle demonstrated a high degree of resistance to babesiosis and anaplasmosis; however, cattle without coinfectious immunity were treated chemotherapeutically to prevent death losses.

96. TODOROVIC, R. A., LOPEZ, L. A., LOPEZ, A. G. and GONZALEZ, E. F.:  
Bovine Babesiosis and Anaplasmosis: Control by Premunition and  
Chemoprophylaxis. *Experimental Parasitology*, (1975), 37: 92-104.

Experiments were carried out to evaluate 2 systems: (1) premunition and (2) chemoprophylaxis for the control of bovine babesiosis and anaplasmosis in the Cauca River Valley, Colombia. Control of these diseases was achieved by inoculating cattle with virulent Babesia bigemina, Babesia argentina, and Anaplasma marginale and subsequent treatment with Imidocarb and Gloxazone to moderate the postpremunition reactions. Chemoprophylactic treatment with Imidocarb and Gloxazone was administered to cattle before and during field exposure. Premunized cattle were highly resistant to tick-borne (Boophilus microplus) challenge. Imidocarb had therapeutic and chemoprophylactic properties against babesiosis, but appeared toxic. Gloxazone moderated the A. marginale postpremunition reaction, but failed to prevent clinical anaplasmosis under the conditions of this investigation.

97. TODOROVIC, R. A. and TELLEZ, C. H.: The Premunition of Adult Cattle  
Against Babesiosis and Anaplasmosis in Colombia, South America.  
*Tropical Animal Health & Production*, (1975), 7: 125-131.

Twenty-five cattle (Bos taurus) between 2 and 3 years of age were premunized with virulent Babesia bigemina, Babesia argentina and Anaplasma marginale. The Babesia spp. premunition reaction was controlled by Imidocarb or by Ganaseg therapy. The A. marginale postpremunition reaction was controlled by oxytetracycline alone, or combined with Gloxazone (dithiosemicarbazone). Systems of premunition for Babesia spp. were found effective and practical; but systems of premunition for A. marginale were found less effective and not practical under the conditions of these experiments.

98. CALDERON, G. A., and TODOROVIC, R. A.: Obtencion de Antigenos para la Prueba de Fijacion del Complemento de Plasma y Eritrocitos Parasitados con Babesia bigemina y Babesia argentina. Revista del Instituto Veterinario de Investigaciones Tropicales y de Altura, Lima, Peru. (1975).

Babesia bigemina and Babesia argentina complement fixation (CF) antigens were isolated from the plasma (P) of acutely infected splenectomized calves, respectively. These antigens were used in CF tests to compare their serologic reactivity with the CF antigens isolated from infected erythrocytes (E). It was found that CF plasma antigens can be used successfully in the CF test for detection of specific Babesia bigemina and Babesia argentina antibodies. This finding is of significant economical and practical importance because the plasma was discarded in procedure for isolation of Babesia species antigens previously reported.

99. VIZCAINO, O. G. and TODOROVIC, R. A.: Caracterizacion de los Antigenos de Babesia argentina y Babesia bigemina por los Metodos de Fijacion del Complemento, Inmunodifusion, Inmunoelectroforesis e Inmunidad Cruzada. Revista ICA, (March 1975), 10: 77-85.

Babesia argentina and Babesia bigemina antigens were isolated from blood of acutely infected splenectomized calves and used in complement fixation tests. Soluble antigens for both B. argentina and B. bigemina were isolated by chromatography with DEAE cellulose and Sephadex G-200 from plasma collected from acutely infected calves and were characterized by means of immunodiffusion and immunoelectrophoresis techniques. The antigens of B. argentina and B. bigemina used in the complement fixation test reacted specifically with the homologous sera and at a lower percentage with the heterologous sera. Soluble antigens of B. argentina and B. bigemina had reactions of identity and non-identity in the double gel diffusion test and detected precipitating antibodies in the serum collected from animals with chronic babesiosis. The soluble antigens of B. argentina and B. bigemina had slow electrophoretic mobility toward the anode with clear precipitation arcs. In the cross immunity studies, a slight cross protection against B. argentina and B. bigemina infections was demonstrated.

100. MAURER, F. D.: African Swine Fever and Hog Cholera - a Comparison. Proceedings of the United States Department of Agriculture Seminar, Athens, Georgia, (January 1976).

This paper designed as a review of these diseases for U.S. veterinarians covered the history of ASF, then compared the etiology, host range, transmission, clinical character, gross and microscopic pathology with hog cholera. Emphasis was placed on those features of each most significant in the differential diagnosis of these very important diseases of swine.

101. WYSS, J. H.: The In Vitro Cultivation of Babesia bigemina Utilizing Bovine Cells in Culture. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, May 1976.

Babesia bigemina in vitro cultivation experiments utilizing primary and continuous monolayer cultures were conducted. Experiments to infect normal non-infected cells by in vitro inoculation using fresh or stabilate B. bigemina-infected blood as inoculum were conducted with primary monolayer cultures of bovine spleen, lymph node, hemal node, and fetal kidney and continuous monolayer cultures of African Green Monkey kidney cells. When fresh infected blood was used as inoculum, the B. bigemina organisms dissociated from their host erythrocytes by day 2 and extracellular parasites were identifiable for up to 5 days on the surface of the cultured cells. When stabilate preparations were used as inoculums, the majority of the parasites remained intraerythrocytic with few extracellular parasites being observed. Babesia bigemina-infected erythrocytes present in the inoculum were observed up to 14 days on the surface of the cultured cells; however, the parasites were degenerative and pyknotic in appearance. No differences were observed between the various types of cultured cells and there was no evidence that parasitic infection of culture cells or multiplication of organisms took place in the original cultures or subsequent subcultures.

Experiments with primary monolayer cultures derived from B. bigemina-infected calves were conducted with spleen, lymph node, hemal node and leucocyte cultures. Five days after culture seeding, B. bigemina organisms could be found only in splenic monolayer cultures and could be identified in such cultures for 11 days post culture. The number of B. bigemina organisms decreased with time and there was no evidence that infection of cultured cells occurred or multiplication of the parasite took place. The subsequent 7 subcultures of the monolayer cultures did not demonstrate any evidence of being infected with B. bigemina and no subcultures of detached cells suspended in media could be established.

Babesia bigemina in vitro cultivation experiments utilizing erythrocyte maintenance suspension cultures were conducted. Experiments to infect normal non-infected erythrocytes maintained in suspension culture were conducted using fresh and stabilate infected blood preparations. In addition, B. bigemina-infected blood was also placed in maintenance cultures. Before the erythrocyte maintenance procedures were improved, a similar situation existed as with monolayer cultures. When fresh infected blood was used as inoculum or placed in maintenance culture, the B. bigemina became extraerythrocytic within 24 hours and failed to infect other non-infected erythrocytes. When stabilate preparations were used, infected ghost erythrocytes were observed up to 2 days. Morphologically the B. bigemina were degenerative. As the erythrocyte maintenance procedures improved, infected erythrocytes were observed up to 4 days and infected erythrocytes held in maintenance culture 3 days were proven infective for a susceptible splenectomized calf.

102. KYZAR, C. T.: Evaluation of a Babesiosis Card Agglutination Test.  
A Thesis submitted to the Graduate College of Texas A&M University  
in partial fulfillment of the requirement for the degree of  
Master of Science, 1976.

A babesiosis card agglutination test (BCT) was evaluated as a means of detecting specific antibodies in cattle infected with Babesia bigemina. The agglutinating antigen was prepared from the blood of a splenectomized calf having a 58% B. bigemina parasitemia.

Two methods of antigen preparation were evaluated, one using a pure B. bigemina parasite suspension and the other a crude suspension of B. bigemina parasites and parasite particles with erythrocytic stroma. The following methods of antigen preservation were evaluated: (1) dilution with phosphate buffered physiologic saline solution (PBS), (2) addition of 0.05% phenol, (3) addition of 0.01% thimersal, (4) addition of penicillin and streptomycin, (5) dilution with Walpole's acetate buffer containing 0.1% methyl-P-hydroxybenzoate, (6) lyophilization, and (7) freezing.

In order to determine suitability for testing, fresh and frozen serum and serum that had remained with the clot for 48 hours and plasma containing sodium citrate, ammonium heparin, and dipotassium ethylenediaminetetraacetic acid (EDTA) as anticoagulants were evaluated.

The BCT was performed on serums and plasma collected from animals experimentally infected with B. bigemina, Babesia argentina, and Anaplasma marginale. Using serum and plasma samples collected from 299 cattle from 4 different ecological areas of Colombia, the BCT was compared to 2 other serological tests, the complement-fixation (CF) test and the indirect fluorescent antibody (IFA) test.

The BCT, using the crude antigen suspension preserved with either the addition of penicillin and streptomycin or dilution with PBS, compared favorably with the IFA test under both laboratory conditions using serums and field conditions using plasma collected with sodium citrate as the anticoagulant. Significant differences were detected when the BCT was compared to the CF test.

103. HOPPS, D. C.: An Evaluation of Colostral Immunity and the Acquired Immune Response to Bovine Babesiosis using the Complement Fixation and the Indirect Fluorescent Antibody Tests. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, (1976).

The complement fixation (CF) and indirect fluorescent antibody (IFA) tests for Babesia bigemina and Babesia argentina were applied to serums collected from 3 experiments. Experiment 1 involved 6 calves infected once with Babesia argentina and 6 calves infected once with Babesia bigemina. In the Babesia argentina infected calves, the CF and IFA titers were positive at the end of one year, and there was only a low level heterologous titer to Babesia bigemina which persisted for 2 to 4 months. In the Babesia bigemina infected calves, homologous CF titers were low and did not persist over 4 months, but heterologous titers to Babesia argentina were higher and persisted for over 7 months. Homologous IFA reactions were of high titer to Babesia bigemina and persisted the entire year; heterologous reactions were of low titer and persisted for only 3 months.

In experiment 2, six calves born in an endemic zone of Colombia were continually exposed to natural tick-transmitted infections of Babesia argentina and Babesia bigemina for one year, but they did not develop clinical babesiosis. Serologic titers were positive for both organisms during the first week of life, and protection from the clinical effects of Babesia infections was considered due to protective antibodies in the colostrum. Repeated natural exposure caused fluctuating positive titers during the first year of life.

In experiment 3, serums were collected from 5 noninfected calves before ingestion of colostrum from cows with antibody titers to babesiosis, and weekly for 6 months thereafter. Highest CF and IFA titers were measured in the serum of each calf at 1 week of age, intermediate titers were measured in the colostrum itself, and the lowest titers were detected in the serum from each cow. Antibodies persisted for as long as 20 weeks, depending on the original titer. Both the CF and IFA tests were approximately equal in their ability to detect colostral antibodies.

The IFA test is recommended as the test of choice for a reliable and sensitive means of obtaining serologic evidence of babesial infection. The CF test, especially for Babesia bigemina, often lacked sensitivity and reliability

104. TODOROVIC, R. A.: Bovine Babesiosis in Colombia. *Veterinary Parasitology*, (1976), 2: 97-109.

Babesiosis is a tick-borne disease of cattle which occurs in many tropical and subtropical areas of the world. Despite the extensive investigations which have been carried out since the discovery of the organism (Babes, 1888) many problems of major importance remain to be solved in Babesia spp. -host complex. In Colombia (South America) the experiments were carried out to identify the existing Babesia spp. by morphologic and immunoserologic methods. The immunoserologic relationship of Babesia spp. were studied by several serologic techniques. Attempts were made to develop a sensitive and practical serologic test for diagnosis of latent Babesia spp. infections. Several groups of intact and splenectomized calves were inoculated with various antigens isolated from Babesia spp. infections and the response to vaccination, premunition and tick-borne challenge were studied. The second part of this investigation was mainly concerned with evaluating the system of chemoprophylaxis against Babesia spp. infections under actual field conditions.

105. TODOROVIC, R. A. and LONG, R. F.: Comparison of Indirect Fluorescent Antibody (IFA) with Complement Fixation (CF) Tests for Diagnosis of Babesia spp. Infections in Colombian Cattle. *Zeitschrift für Tropenmedizin und Parasitologie*, (1976), 27: 169-181.

A total of 372 serum samples were collected from Colombian cattle before and during the course of natural Babesia spp. infection on the North Coast of Colombia. The serum samples were used to compare indirect fluorescent antibody (IFA) with complement fixation (CF) tests for diagnosis of babesiosis. The IFA technique detected Babesia argentina antibodies an average of 4.0 weeks earlier than the CF test and Babesia bigemina an average of 2.5 weeks earlier. Both IFA and CF were capable of differentiating B. argentina and B. bigemina infections, however in some cases cross reactions were observed. In general IFA titers were at relatively high levels of 1:640 to 1:5120 in comparison with CF titers of trace to 1:80. In cases of mortality due to babesiosis, both IFA and CF serologic techniques were very useful in indicating the cause of death. Although both IFA and CF are laboratory tests, the IFA technique had advantages over the CF in simplicity, economy and speed of performance.



106. THOMPSON, K. C. and ROA, J. C.: The Transmission of Anaplasma marginale by the Tropical Cattle Tick Boophilus microplus. International Conference of Tick-borne Diseases and their Vectors, University of Edinburgh, Centre of Tropical Veterinary Medicine, Edinburgh, Scotland, (September, 1976).

Laboratory Boophilus microplus tick strains were used to infest splenectomized Holstein-Friesian calves infected with a purified Anaplasma marginale stabilate. The engorged B. microplus females were held in tick incubators (70 + % relative humidity at 28 to 30° C) during oviposition. The resulting larvae were used for the subsequent transmission trails when they were 14 to 21 days of age.

After eight repeated tick transmission trials, the only successful modes of Anaplasma transmission were by trans-stadial and intrastadial methods. Transovarial (biological) transmission did not occur.

It is suggested that for a tick species to be an efficient mechanical vector of Anaplasma, it would most likely be a two or three host tick and not a one host tick. This would hold true only if there were no great amount of intrastadial movement (especially of males) between cows.

107. THOMPSON, K. C.: The Problem of Bos Taurus Cattle Introduced into the Tropical Areas of Colombia. Second International Conference of Institutions of Tropical Veterinary Medicine, West Berlin, Germany, (October 1976).

Invariably the greatest problem imposed on any introduced breed of cattle into the tropics is one of acclimatization. Not only does the lack of photoperiod seasonality, temperature and humidity play havoc (often sterility; drop in milk production), but inefficient utilization of tropical forages and protein supplements may also cause intermittent profuse diarrhea with subsequent drastic loss of body weight.

After this period (which differs between breeds), one usually finds ticks with their diseases (anaplasmosis and/or babesiosis) taking their toll.

Surviving this, one has the age old problems of different cultural practices of cattle management to deal with along with other infectious (brucellosis, foot and mouth, clostridial diseases, anthrax, leptospirosis, IBR) and non-infectious (mastitis, foot rot, screw worm) disease syndromes.

Hence, any procedure designed to lessen or alleviate any or all of these effects, results in greater economical gain for the cattleman.

108. THOMPSON, K. C.: A Technique to Establish a Laboratory Colony of Boophilus microplus Infected with Babesia bigemina. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, (February, 1976). (abstract)

A technique was evolved for the establishment and maintenance of a colony of Boophilus microplus free of infection with Anaplasma marginale and Babesia spp., and for their subsequent infection with a pure isolate of Babesia bigemina. Confirmation was obtained that the ticks are infected normally during the last 24 hours of attachment on the host. The life cycle of Boophilus microplus was described for a single situation on the Atlantic Coast of Colombia.

109. GONZALEZ, E. F., TODOROVIC, R. A., and THOMPSON, K. C.: Immunization against Anaplasmosis and Babesiosis: Part I. Evaluation of Immunization Using Minimum Infective Doses under Laboratory Conditions. *Tropenmed. Parasit.*, (1976), 27: 427-437.

A method of immunization against anaplasmosis and babesiosis using minimum infective doses was developed under laboratory conditions. Stabilates of Anaplasma marginale stored at  $-60^{\circ}\text{C}$  were found infective when diluted 10-fold to  $10^{-3}$ . Stabilates of Babesia argentina and Babesia bigemina stored under the same conditions were infective when diluted 10-fold to  $10^{-1}$ . Intact calves inoculated with the above dilutions of stabilates developed moderate parasitemias and recovered from infection without treatment. There was an immune response to vaccination with the formation of specific antibodies to A. marginale, B. bigemina and B. argentina as measured by the complement fixation (CF) test. All calves were found resistant to artificial challenge with lethal doses of the respective parasites.

110. TODOROVIC, R. A., LONG, R. F., MCCALLON, B. R.: Comparison of Card Agglutination Test with the Complement Fixation Test for Diagnosis of Anaplasma marginale Infection in Colombian Cattle. Veterinary Microbiology, (1977), 2: 167-177.

342 serum samples were collected from 9 Holstein-Friesian calves before and during natural infection with Anaplasma marginale on the North Coast of Colombia. The samples were used to compare the complement fixation (CF) and rapid card agglutination tests (CT) for the diagnosis of anaplasmosis. The positive agglutination of the CT always developed several days after the first CF reaction but then persisted. In contrast, the CF test showed an initial sharp rise in titer but then showed fluctuations between trace and 1:80 titers. The results indicated that under field conditions the CT was the simpler and more reliable test for the diagnosis of anaplasmosis in a single animal. The CF test remains useful in experimental situations where the earliest knowledge is required of the magnitude of immunological response to challenge.

111. THOMPSON, K. C., TODOROVIC, R. A., and HIDALGO, R. J.: Antigenic Variation of Babesia bigemina, Research in Veterinary Science (1977), 23: 51-54.

The purpose of the study was to determine whether antigenic differences occurred in four stabilates of Babesia bigemina derived from a single purified isolate and propagated as acute and chronic, blood-borne and tick-borne infections in Colombian cattle.

Antigens were characterised by means of the complement fixation (CF), gel diffusion (GD), agar gel electrophoresis (AGE) and the indirect haemagglutination tests (IHA).

Differences were detected. Acute blood and chronic blood antigens were similar, as were acute tick and chronic tick antigens, when compared by IHA and GD. Similarities were observed between acute blood and acute tick and between chronic blood and chronic tick when these antigens were compared by AGE and CF.

112. LONG, R. F., GONZALEZ, E. F., GUZMAN, M. L. and TODOROVIC, R. A.: An Indirect Fluorescent Antibody (IFA) Procedure for the Diagnosis of Bovine Anaplasmosis and Babesiosis. VIII Congreso Panamericano de Medicina Veterinaria y Zootecnia, Santa Domingo, Republica Dominicana. (1977).

A rapid accurate, reproducible serological test in which the easy preparation of antigens, simple storage requirements, minimum use of expensive materials and the capability of simultaneous testing of sera for multiple hemoparasite antibodies are combined to provide clinical or research laboratories and veterinarians with valuable diagnostic tool.

Detailed instructions for antigen preparation, test performance and interpretation of results are given and potential trouble areas are discussed and practical remedies outlined.

113. KUTTLER, K. L., ADAMS, L. G., and TODOROVIC, R. A.: Comparison of the Complement Fixation and Indirect Fluorescent Antibodies. American Journal of Veterinary Research. (1977), 38: 153-156.

Complement-fixation (CF) and indirect fluorescent antibody (IFA) antigens were prepared from Babesia bigemina isolates obtained in Texas. These serologic procedures were evaluated on 130 serum samples sequentially collected from 5 B. bigemina infected mature cattle, beginning on the day of exposure and continuing for 175 days thereafter.

Both tests were effective in detecting specific antibodies for the first 84 days of infection, with 57 of 60 (95%) serums tested being positive on the CF test and 57 of 57 (100%) tests being positive to the IFA test. During the interval from 98 to 175 days, 24 of 60 (40%) of the serums tested were positive with the CF test, and 53 of 56 (95%) were positive with the IFA test.

During the first 84 days, a similar linear regression occurred in both CF and IFA serum titers, but after 98 days the IFA regression flattened out, whereas the CF titers decreased below the sensitivity threshold in 60% of the serums tested.

114. THOMPSON, K. C.: El Problema de la Introduccion de Ganado Bos taurus a las Zonas Tropicales de Colombia. Revista El Cebie, Volume XVI Ano XXII, Bogata, Colombia, (Oct./Nov., 1977), 184: 18-19.

Existe la creencia entre los ganaderos de America Tropical, de la necesidad de introducir ganado Bos taurus como elemento mejorante de las razas nativas. Esta creencia se basa en la mayoria de los casos en estudios economicos realizados en paises de ecologia diferente a la nuestra, con una tradicion ganadera respaldada por muchos anos de experimentacion y desarrollo tecnologico.

115. THOMPSON, K. C., TODOROVIC, R. A. and HIDALGO, R. J.: The Immune Responses to Antigenic Variants of Babesia bigemina in the bovine. Research in Veterinary Science, (1977), 24: 1-4.

Four Babesia bigemina stabilates were used to determine the immune response of cattle to acute and chronic-blood and tick-borne infections.

Thirty-two intact calves were divided into 16 groups of 2 and each calf was inoculated with infective B. bigemina erythrocytic stabilates. Twenty-eight days later they were challenged with homologous and heterologous stabilates, and monitored for an additional 20 days. The hosts apparently reduced response to homologous challenge indicated antigenic differences between the isolates and confirmed the conclusions reached by examination of the serological data.

116. LOPEZ, G. V., TODOROVIC, R. A.: Rapid Latex Agglutination Test (RA) for the Diagnosis of Babesia argentina Infection. Veterinary Parasitology, (1978), 4: 197.

A rapid test, utilizing latex particles (0.81-um diameter), sensitized with Babesia argentina antigens, proved to be effective in the diagnosis of B. argentina in natural and experimental infections. Two drops of plasma or serum and one drop of B. argentina antigen placed on a glass plate were used in the test. Reaction was observed after 3-10 minutes rotation. The positive agglutination reaction was characterized by the formation of fine latex particle clumps. In experimental infections with B. argentina, the first detectable positive agglutination reactions coincided with the appearance of parasitemia in thin blood films. Plasma from animals with natural infections of B. argentina, proven by blood smears and indirect fluorescent antibody and complement fixation tests, also showed a reaction to the latex agglutination test.

117. TODOROVIC, R. A., and GARCIA, R.: Comparison of the Dried Blood on Filter Paper and Serum Techniques for the Diagnosis of Bovine Babesiosis Utilizing the Indirect Fluorescent Antibody (IFA) Test. *Tropenmedizin u Parasitologie*, (1978), 29.

A comparison between the techniques of dried blood on filter paper and serum for the diagnosis of babesiosis utilizing the indirect fluorescent antibody (IFA) test was evaluated. Dried blood on filter paper was used as a method to detect B. bigemina and B. argentina antibodies of Colombian cattle under laboratory and field conditions and the technique was compared with the serum of the same animals. A high relationship was found between the results of the dried blood and the serum from calves experimentally infected with Babesia spp. and calves from enzootic hemoparasites-free zones in Colombia. There were no significant differences in the sensitivity and specificity of both techniques. The samples on filter paper could be practical for field use due to their easy management and storage at different temperatures. This indicates that the use of dried blood may be a valuable aid for the epizootiologic studies of Babesia spp. infections in bovines.

118. THOMPSON, K. C., TODOROVIC, R. A., MATEUS, G. and ADAMS, L. G.: Methods to Improve the Health of Cattle in the Tropics. Immunisation and Chemoprophylaxis Against Haemoparasitic Infections. *Tropical Animal Health Production*, (1978), 10.

A study of methods to improve the health of native cattle in tropical areas of Colombia showed an advantage using immunisation techniques against haemoparasitic infections in comparison with other control methods. The control of anaplasmosis and babesiosis by immunisation of cattle with full virulent Anaplasma marginale, Babesia argentina and B. bigemina is feasible in tropical cattle when the post-immunisation reaction is controlled by appropriate drug therapy. Chemoprophylaxis was found less effective in controlling haemoparasitic diseases; however, treated cattle surviving the acute stage of infection showed weight gains not significantly different from those of the immunized calves. Both methods were found to be advantageous with calves born and raised in an endemic area of anaplasmosis and babesiosis. Tick and gastro-intestinal parasitic control without haemoparasitic control in calves had an advantage over no control system at all. These methods though were inferior to the immunization and chemoprophylactic techniques.

119. KYZAR, C. T., THOMPSON, K. C., and GONZALEZ, E. F.: Visualization of Babesia bigemina and Associated Bodies by Acridine Orange Staining, Libro Azul, Hoechst, Germany. (1977)

Using the described acridine orange technique the erythrocytes appear as olive green discs on a dark background, and the Babesia bigemina organisms stain as orange pyriform bodies. Associated with the infection are often found small round green bodies which may be seen in both infected and non-infected erythrocytes or free in the plasma. The theory is given that these small bodies are the infective units of B. bigemina.

120. CORRIER, D. E., CORTES, J. M., THOMPSON, K. C., RIANO, H., BECERRA, E. and RODRIGUEZ, R. A Field Survey of Bovine Anaplasmosis, Babesiosis and Tick Vector Prevalence in the Eastern Plains of Colombia. Tropical Animal Health Production, (1977).

The prevalence of Anaplasma marginale, Babesia bigemina and Babesia argentina serological reactors in 37 cattle herds in the eastern plains of Colombia was found to be 74, 62 and 13 percent, respectively. Boophilus microplus was the only cattle tick equally distributed across the region.

121. KUTTLER, K. L.: East Coast Fever (Theileriasis, Theileriosis, Rhodesian Tick Fever, Rhodesian Red Water). "Foreign Animal Diseases" manual, U.S. Animal Health Assoc., (1976), 85-95.

A general discussion of East Coast Fever was presented with emphasis on diagnosis, epizootiology, and control. This disease is a highly pathogenic, tick transmitted, febrile infection of cattle, caused by the protozoan parasite Theileria parva, which primarily involves the lymphopoietic and hemopoietic systems. It is a serious economic constraint to profitable cattle production primarily in East Africa where the principle vector, Rhipicephalus appendiculatus, occurs.

122. KUTTLER, K. L., and TODOROVIC, R. A.: Arthropod Borne Protozoan Infections (Affecting Domesticated, Food-Producing Animals.) "Foreign Animal Diseases" manual, (1973), 291-322.

The arthropod borne protozoan infections include a wide range of infectious agents which are generally hemotropic in nature and are transmitted by blood sucking insects such as ticks, flies, mosquitoes, etc. Transmission may occur mechanically by the transfer of infected blood from one animal to another by insects or improperly cleaned surgical instruments. More often, biological vectors are involved, in which the causative agent undergoes cyclical development in the invertebrate host, prior to producing infection in the susceptible vertebrate host.

These protozoan agents may be extra- or intra-erythrocytic in nature, but are generally characterized by febrile reactions in the acute phase, varying degrees of anemia, and carrier infections following recovery.

Included under this heading are diseases caused by Theileria, Trypanosoma, Anaplasma, Babesia, Leucocytozoon, and Besnoitia. A list of agents with the disease they produce, animal species affected, and the principal vectors is given in Table 1. East Coast Fever (Theileria) and trypanosomiasis (Trypanosoma) have been discussed in detail in separate chapters. Babesiosis and anaplasmosis, major animal disease problems throughout the world, are discussed in some detail in this chapter.



123. MILLER, R. M., PRICE, M. A., KUTTLER, K. L.: Investigations on Transstadial Transmission of Bovine Anaplasmosis and Beginn Bovine Theileriosis in Cattle by Two Species of Amblyoma (Acarina: Ixodidae). The Southwestern Entomologist, 1, (3), (September 1976): 107-110.

Amblyomma americanum and Amblyomma cajennense nymphal stages were fed on Anaplasma and Theileria infected cattle. Following molting, adult ticks were fed on susceptible splenectomized calves in an effort to demonstrate transmission. In no instance was an infection of either Anaplasma or Theileria produced by either of the tick species tested.

124. YOUNG, M. F., KUTTLER, K. L., ADAMS, L. G.: Experimentally Induced Anaplasmosis in Neonatal Isohemolytic Anemia Recovered Calves. American Journal of Veterinary Research, (1977), 38 No.11: 1745-1747.

Anaplasma marginale infections were induced in 3 calves previously affected with neonatal immunohemolytic anemia (NIA). Similar infections were induced in 6 splenectomized and 7 intact calves. The response to infection by 3 calves (NIA recovered) closely resembled infections seen in splenectomized calves, being markedly more severe than similar infections in intact calves.

Spleens from 3 (NIA recovered) calves after splenectomy were about one-tenth normal size. Marked recrudescing anaplasma infections were not detected after splenectomy of the calves (NIA recovered), whereas marked recrudescing infections were observed after splenectomy of 2 intact calves having recovered from the primary infections.

125. KUTTLER, K. L. and JOHNSON, L. W.: Anaplasma and Babesia Premunition of Two-Year-Old Holstein Heifers Destined for Shipment to Nicaragua. VM/SAC, (1977), 1354-1358.

Nineteen Holstein-Friesian heifers were preimmunized by injection of diluted bovine blood stabilates containing Babesia bigemina, Babesia argentina, and Anaplasma marginale. An additional 20 heifers were preimmunized with a bovine blood stabilate of A. marginale only. Twenty of the 39 animals were given an attenuated strain (DAM) of A. marginale, and 19 were given a non-attenuated strain (TAM). Treatment consisting of one injection of 6.6 mg/kg oxytetracycline was administered to 19 of the heifers that received DAM or TAM stabilates. Twenty head received no treatment. There were 10 non-infected controls.

All 39 heifers receiving A. marginale, either DAM or TAM, showed evidence of replicating infections, resulting in preimmunization. No deaths occurred in the treated or untreated groups. Treatment had only a minimal, non-significant effect on packed red cell volumes and weight gains. Cattle receiving DAM showed significantly milder response compared to the response of those receiving TAM. Cattle that were also infected with Babesia had significantly prolonged incubation times for both DAM and TAM infections, but no other effects were observed.

Evidence of replicating infections was seen in 18 of 19 heifers preimmunized with B. bigemina. Seventeen of 19 cattle given B. argentina were assumed to be preimmunized. This assumption was based on either a positive parasitemia or positive complement-fixation response to B. argentina antigen.

All cattle were shipped to Nicaragua at the completion of the trials, where they were apparently resistant to field challenge.

126. KUTTLER, K. L. and ADAMS, L. G.: Influence of Dexamethasone in the Recrudescence of Anaplasma marginale in Splenectomized Calves. American Journal of Veterinary Research, (1977), 38: 1327-1330.

Dexamethasone was administered at the dose rate of 0.2 mg/kg of body weight to 11 splenectomized Anaplasma-carrier calves (groups 1 and 3) on Monday, Wednesday, and Friday for 3 weeks. Observations were made on these calves and on 7 nontreated, comparable calves (group 2) to determine the influence of treatment on carrier infections.

Dexamethasone treatment was associated in every instance with an exacerbation of the Anaplasma parasitemia and a decrease in packed red cell volume. The episode of acute anaplasmosis was of short duration, resembling the primary response, except that complement-fixation response did not increase accordingly. Serum protein electrophoresis of serums from 4 calves (Group 3) undergoing the drug-induced response failed to show any significant change during the 3-week treatment period, but did show a significant increase in  $\alpha$ -globulin immediately after treatment.

127. KUTTLER, K. L., YOUNG, M. F. and SIMPSON, J. E.: Use of an experimental long-acting Oxytetracycline (Terramycin L/A) in the Treatment of Acute Anaplasmosis. VM/SAC, (February, 1978), 187-192.

Anaplasmosis was induced in 43 adult cows ranging from 6 to 9 years of age. When the subsequent Anaplasma marginale parasitemia reached a level of 4 to 10%, 15 cows were treated intramuscularly with 20 mg/kg of Terramycin /LA (T-200). This formulation has been compounded to provide sustained oxytetracycline plasma levels for three to five days. An additional 15 infected cows were treated on two successive days with 10 mg/kg/day of Liquamycin (T-50), also given intramuscularly. The 13 remaining cows served as infected, nontreated controls.

Both oxytetracycline formulations were highly effective in moderating the course of infection and resulted in rapid recovery. In comparison, 2 Of 13 nontreated controls died and the survivors showed higher parasitemias, lower packed cell volumes, and greater weight loss than did the treated animals. There were no significant differences between the two treatment groups. One injection of the T-200 (200 mg oxytetracycline/ml) was comparable in efficacy to two injections of the T-50 (50 mg oxytetracycline/ml.). Because of the concentration, the required volume of T-200 was only one-fourth that of T-50.

128. KUTTLER, K. L., MCWHORTER, G. M.: Review of Cattle Fever Ticks and Disease They Transmit in New South Wales and Queensland, Australia, TAES DIR, No. 77-1, (1977).

Because of persistent Boophilus infestations and the threat of disease transmission in Texas, the Texas Agricultural Experiment Station (TAES) has assembled a team of agricultural scientists representing wildlife sciences, animal science, range science, agricultural economics, entomology and veterinary medicine to study this problem.

To assist in the establishment of research priorities in Texas, representatives from Texas A&M University (TAES) visited Australia during the month of February 1977 to review Boophilus tick and tick-borne disease research. Australia had been faced with a tick problem similar to that of the United States prior to tick eradication in the early 1940's. Boophilus microplus ticks were introduced into the northern territory in 1872 from whence they rapidly spread down the east coast of Australia into New South Wales (NSW), then westward from the coast until climatic factors limited tick survival. Because of the importance of the livestock industry to the Australian economy a large scale dynamic research program has evolved and is one of the most advanced in the world. Task Force representatives Dr. Kuttler (Veterinary Medicine) and Dr. McWhorter (Entomology) spent 4 weeks in Australia visiting research facilities, field programs involving tick control and regulatory officials to review Boophilus and Babesia research from the Australian perspective. The following installations, facilities, and people were visited.

129. KUTTLER, K. L., SIMPSON, J. E.: Comparative Efficacy of Two Oxytetracycline Formulations and a Synthetic Antibacterial in the Treatment of Anaplasmosis. 8th Pan American Veterinary Congress, Santo Domingo, D.R., (August, 1977), (abstract).

An experimental oxytetracycline injectable (Terramycin/LA), formulated to contain 200 mg/ml (T-200), and a synthetically derived tetracycline (doxycycline), formulated to contain 100 mg/ml (D-100), were compared with the commercially available oxytetracycline (Liquamycin) containing 50 mg/ml (T-50) in the treatment of induced anaplasmosis in splenectomized calves.

All experimental animals were exposed to Anaplasma marginale by the inoculation of known infected stabilates. A total of 23 splenectomized calves were infected, divided into 5 groups and treated as indicated when the ascending parasitemia reached 1-4%. Five calves served as untreated controls; 4 calves were treated 1 time with 10 mg/kg T-50 intramuscularly (I.M.); 5 calves were treated 3 times at 24 hour intervals with 10 mg/kg T-50 I.M.; 5 calves were treated 1 time with 20 mg/kg, T-200, I.M., and 4 calves were treated 1 time with 10 mg/kg, D-100, I.M.

All control calves died from acute anaplasmosis, and one calf treated once with T-50 died. No other deaths occurred. All treatments were effective in moderating the infectious process, but the T-50 given 3 times and the T-200 given 1 time were significantly more effective than T-50 given 1 time and the D-100 given 1 time.

In a second experiment, A. marginale infections were induced in 43 Aberdeen Angus cows averaging 6.9 years of age. These cattle were divided into 3 groups and 2 groups were treated when the ascending parasitemia reached 4-10%. The remaining group served as untreated controls. Fifteen cows were treated 2 times, 24 hours apart, with 10 mg/kg T-50 I.M. Fifteen cows were treated 1 time with 20 mg/kg T-200.

Among the 13 non-treated control cows 2 died, and all showed evidence of acute anaplasmosis. Treatments with T-50 twice, and T-200 once were both effective in moderating the course of infection. Highly significant values in favor of both treated groups were observed when compared with the non-treated controls, but no significant differences in the course of infection were apparent between the 2 treatment groups. One injection of the T-200 was therapeutically comparable to 2 injections of T-50. A 454 kg cow treated with T-50 at the rate of 10 mg/kg twice received 182 ml of the drug I.M., whereas only 45 ml of the T-200 was required to produce comparable results.

130. KUTTLER, K. L., SIMPSON, J. E.: Relative Efficacy of Two Oxytetracycline Formulations and Doxycycline in the Treatment of Acute Anaplasmosis in Splenectomized Calves. *American Journal of Veterinary Research*, (February, 1978), 39: 347-349.

The efficacy of 3 antibiotic formulations was measured in the treatment of artificially induced anaplasmosis in the early stages of an ascending parasitemia (1% to 4%) in 23 splenectomized calves. Group 1, consisting of 5 calves, served as nontreated controls. Four calves (group 2) were treated 1 time with 10 mg of oxytetracycline (T-50)/kg of body weight I.M.; 5 calves (group 3) were treated 3 times with 10 mg of T-50/kg I.M.; 5 calves (group 4) were treated 1 time with 20 mg of an experimental oxytetracycline (T-200)/kg I.M.; and 4 calves (group 5) were treated 1 time with 10 mg of a synthetically derived antibacterial agent, doxycycline (D-100)/kg I.M.

All control calves died and 1 of 4 calves died that was treated 1 time with T-50. Other deaths did not occur. All treatments were effective in moderating the infective process, but T-50 given 3 times and T-200 given 1 time were markedly more effective than T-50 and D-100 given 1 time.

There appeared to be little or no difference in therapeutic efficacy between T-50 and D-100 given 1 time and between T-50 given 3 times and T-200 given 1 time.

131. KUTTLER, K. L.: Anaplasmosis in White-Tailed Deer-Submitted for Publication as a Chapter in a volume entitled Diseases of White-Tailed Deer.

Anaplasmosis in white-tailed deer (WTD) (Odocoileus virginianus) is an infectious, non-contagious disease capable of producing a mild anemia with spontaneous recovery characterized by a persisting chronic non-apparent infection. It is caused by the microorganism, Anaplasma marginale which invades the erythrocytes where it is thought to multiply by binary fission, eventually escaping to infect other erythrocytes, being transmitted from one animal to another by arthropod vectors or the inoculation of infected blood. Anaplasmosis is primarily a disease of cattle where it produces acute or sub-acute infections, characterized by severe anemia, high fever, and icterus. Death is not uncommon in cattle, and when recovery does occur, severe weight and production losses usually accompany and follow infections.

Anaplasmosis at one time was thought to be confined to the tropics and sub-tropics, affecting only cattle, but it is now recognized throughout the world where suitable vectors occur. The Anaplasma organism cannot be propagated on chick embryo, or in small laboratory animals, but will infect a wide range of wild ruminants including deer (Odocoileus virginianus, O. hemionus hemionus, O. hemionus columbianus), elk (Cervus canadensis canadensis), bighorn sheep (Ovis canadensis canadensis), pronghorn antelope (Antilocapra americana), and many African antelope.

Infections produced in species other than cattle are usually mild and often non-apparent. The greatest concern of anaplasmosis in wild animals involves the epizootiological aspects in which these secondary hosts act as reservoirs of infection for cattle.

132. THOMPSON, K. C., ROA, J. E., and ROMERO, T.: Anti-tick Grasses as the Bases for Developing Practical Tropical Tick Control Packages. Tropical Animal Health and Production, (1978).

Of six grass species analysed, Melinis minutiflora (Molasses grass) showed the highest anti-tick deterrent properties while Andropogon gayanus (Gamba grass) exhibited the ability to maintain a defined, constantly low, initial host tick infestation property and lengthy but low to moderate field tick population.

The conclusion is that Molasses grass is a species which would best be used in a tick control package within a marginal tick zone while Andropogon has the advantage within an endemic tick zone.

The goal being to produce an economical, practical tick control package by using anti-tick pastures plus limited, strategic acaricide application which will yield low cost, efficient tick control and an increased beef production for the small livestock producer who lacks the resources for conventional tick control methods.

133. TODOROVIC, R. A., and GONZALEZ, E. F.: Immunization Against Bovine Babesiosis Using a Live Vaccine. *Revista ICA*, 10: 243-254.

Forty male calves, Holstein-Friesian, were used to evaluate various systems of immunization against bovine babesiosis using a vaccine containing live Babesia parasites. Two methods were utilized to produce immunity: the first was using blood from animals carriers of B. bigemina and B. argentina, and the other one was using blood from splenectomized calves inoculated with B. bigemina and B. argentina and collected during the acute time of infection. The degree of resistance was measured by natural challenge to ticks (B. microplus) infected with Babesia in an endemic area of Cauca Valley. The premunized cattle showed a high degree of resistance against babesiosis while the control group, non premunized, was treated to prevent mortality. The response to vaccination was much better in cattle premunized with blood from a carrier animal. Weight gains were compared in vaccinated and nonvaccinated animals. There was a slight decrease in weight two months after vaccination but once the calves were exposed to the field challenge, the control group lost 53 kg in average during the six months following the exposure to ticks, compared with the vaccinated group.

134. GONZALEZ, E. F., TODOROVIC, R. A., LOPEZ, G., and GARCIA, O.: Attenuation of a Babesia Argentina isolate of Colombian Origin. *Scientific Proceedings of X World Congress of Buiatrics, Mexico*, (1978).

Babesia argentina (B. bovis), isolated in Monteria, Colombia, in 1971 was attenuated by continuous passages in splenectomized calves. The attenuated behavior was observed beginning with the 23 passage. A comparative statistical study made in a group of 60 cattle inoculated with  $10^{10}$  B. argentina parasites showed significant comparative results between groups of animals inoculated with the virulent (passage No. 6) and attenuated (passage No. 27) parasites and a non-inoculated group. Of the 20 animals inoculated with the virulent parasite, 19 showed clinical symptoms of acute babesiosis and 9 animals died between days 11 and 14 post-inoculation (PI). None of the 30 animals inoculated with the attenuated parasite showed clinical symptoms of the disease. Only a slight decrease in average hematocrit on day 14 PI (-6.5%) and slight rise in the average temperature on day 11 PI (+.32°C) were observed. The implications of the utilization of this attenuated B. argentina parasite for the control and prevention of bovine babesiosis are obvious.



135. TODOROVIC, R. A.: Hemoparasite Control in Bovine., Proceedings of the 20th World Veterinary Congress, 6-12 July, 1975, Thessaloniki, Greece, Vol. 1, 569-581.

Bovine babesiosis is a widely spread disease in the tropical and subtropical areas of the world where ticks exist. A program of vector control using chemical methods decreases the incidence of the disease but it still is a problem which causes great economic losses in these areas of the world. Other control methods such as artificial immunization with blood from infected animals (premunition) and chemo-prophylaxis have been used.

Two systems of immunization against babesiosis have been evaluated under experimental and field conditions. The first system is based on obtaining a co-infectious immunity (premunition) using two methods: (a) with blood from calves with acute infections of B. bigemina and B. argentina used as inocula and controlling the post-inoculation reaction with specific drugs and (b) inducing an artificial infection with blood of calves that are infected carriers of B. bigemina and B. argentina without chemotherapy. For this trial, 48 intact and 8 splenectomized calves were used. The degree of resistance was determined by artificial inoculation of infected blood and exposition to ticks under field conditions. The premunized cattle showed a high degree of resistance against babesiosis, however, the non-premunized cattle had to be treated since they suffered a severe attack of babesiosis.

The second system is based on obtaining a sterile immunity using dead Babesia bigemina and Babesia argentina parasites and their antigens as inocula. For this, vaccines were prepared from infected erythrocytes (AG-E) and infected plasma (AG-S). The vaccines were tried in cattle under field conditions, using 20 calves which were distributed into 4 groups of 4 calves each and one control group. The immunological responses were measured by hematocrit value, parasitemia, complement fixation, weight and mortality. It was found that a good degree of sterile immunity against babesiosis could be produced using a dead vaccine based on these parasites, which indicates that it plays an important role in the mechanism of immunity against bovine babesiosis.

136. TODOROVIC, R. A., GONZALEZ, E. and LOPEZ, G.: Immunization Against Anaplasmosis and Babesiosis. Part II. Evaluation of Cryo-Preserved Vaccines Using Different Doses and Routes of Inoculation. VIII Panamerican Congress of Veterinary Medicine and Zootechnics, Santo Domingo, Dominican Republic, (August, 1977).

Anaplasma marginale, Babesia argentina and Babesia bigemina infected blood used as vaccines for immunization trials in Valle del Cauca, were preserved with 4 Molar Dimethyl-Sulfoxide (4M DMSO) and stored in liquid nitrogen (-196°C). The effectivity of the vaccines was determined in 87 healthy calves utilizing serial 10-fold dilutions. The effects of dose, inoculation routes, time and temperature were determined. The minimum infective dose for A. marginale was  $10^{-3}$  ( $2 \times 10^6$ ) when 2 ml of vaccine were given intravenously (i.v.). The same dose when given subcutaneously (s.c.) was not infective. The  $10^{-2}$  dilution ( $2 \times 10^7$ ) was infective when given through both routes, however, the incubation periods were statistically different. The average incubation period using 2 ml s.c. was 30 days, but when the dose was increased to a 5 ml and given s.c. decreased the average incubation period to 22 days. The minimum infective doses for B. bigemina and B. argentina were  $10^{-1}$  dilutions ( $4 \times 10^{-7}$ ) and  $10^{-2}$  ( $4 \times 10^6$ ) respectively, when 2 ml of vaccines were injected i.v. Infectivity was also recorded when Babesia spp. vaccines were injected s.c. at dosages of 5 ml of dilution  $10^{-1}$  ( $1 \times 10^{-8}$ ).

137. GONZALEZ, E. F. and TODOROVIC, R. A.: Economical Impact of Anaplasmosis and Babesiosis in a Dairy Herd From an Endemic Area of Colombia. VIII Congreso Panamericano de Medicina Veterinaria y Zootecnia, Santo Domingo, Republica Dominicana, (1977). Abstract.

138. ALIU, Y.O., DAVIS, R.H., JR., CAMP, B.J., and KUTTLER, K.L.: Absorption, Distribution, and Excretion of Imidocarb Dipropionate in Sheep. American Journal of Veterinary Research, (December, 1977), 12, (12): 2001-2006.

Spectrophotometric and thin-layer chromatographic methods for determination of imidocarb in biological specimens are described.

Following intravenous injection of imidocarb (2.0 mg/kg) into 3 sheep, plasma concentrations, initially averaging 10.8  $\mu\text{g/ml}$ , decreased to an average of 1.9  $\mu\text{g/ml}$  within 1 hour and then to less than 1  $\mu\text{g/ml}$  within the next 4 hours. When imidocarb (4.5 mg/kg) was injected intramuscularly (IM) into 7 sheep, peak plasma concentrations averaging 7.9  $\mu\text{g/ml}$  were achieved within 4 hours and then rapidly decreased to 4.6  $\mu\text{g/ml}$  within the next 2 hours. Plasma values then decayed very slowly by first-order kinetics and trace amounts were still present 4 weeks after treatment. Imidocarb was bound to plasma proteins and the apparent volume of distribution was estimated to be slightly higher than the total body water. The concentrations of the drug in the plasma and in the erythrocytes were approximately equal. Detectable amounts were present in all examined tissues 4 weeks after IM administration. Twenty-four hours after IM administration, the highest concentrations were in kidney, liver, and brain. The C-labeled imidocarb could be detected in all regions of the central nervous system examined, in the hypophysis, and in the pineal body.

Metabolic or biotransformation products were not detected by the methods used. Of the administered IM dose, 11 to 17% was excreted in the urine within 24 hours; thereafter, the excretion rate was low, and detectable amounts were still present in the urine for 4 weeks. Renal clearance of imidocarb was less than glomerular filtration rate, indicating net tubular reabsorption.

The relatively high concentration of imidocarb in the bile suggests that the bile is an important route of excretion. High concentrations were also found in the milk of lactating ewes, but the drug could not be detected in the plasma of lambs fed milk from these ewes.

MANUSCRIPTS IN PREPARATION  
SUBMITTED TO SCIENTIFIC JOURNALS

OR

ACCEPTED FOR PUBLICATION

1. FURNISS, Sean B. and THOMPSON, K. C.: Birds in Colombia as Host for Ticks.
2. GONZALEZ, E. F., LONG, R. F., TODOROVIC, R. A.: Comparisons of the Complement-Fixation, Indirect Fluorescent Antibody and Card Agglutination Tests for the Diagnosis of Bovine Anaplasmosis.
3. LOPEZ, G. V., THOMPSON, K. C. BAZALAR, H.: Transmission Experimental de Trypanosoma Vivax por la Garrapata Boophilus Microplus.
4. THOMPSON, K. C. and ROA, J. C.: Transmision de Anaplasma marginale por la Garrapata Boophilus microplus.
5. THOMPSON, K. C., TODOROVIC, R. A., MATEUS, G. and ADAMS, L. G.: Methods to Improve the Health of Cattle in the Tropics: Conclusion and Economical Appraisal.
6. THOMPSON, K. C., TODOROVIC, R. A., MATEUS G., ADAMS, L. G.: Methods to Improve the Health of Cattle in the Tropics: Ecto-and Endoparasite Control.
7. GONZALEZ, E. F., CORRIER, D. E., TODOROVIC, R. A. and LOPEZ, G.: Epidemiology of Bovine Anaplasmosis and Babesiosis in the Cauca River Valley.
8. TODOROVIC, R. A., GONZALEZ, E. F. and GARCIA, O.: Evaluation of Different Immunization systems to Control Bovine Anaplasmosis and Babesiosis.
9. GARCIA, O., TODOROVIC, R. A., AND GONZALEZ, E. F.: Evaluation of Mono and Bivalent Vaccine Systems against Bovine Babesiosis.
10. TODOROVIC, R. A., GONZALEZ, E. F. and GARCIA, O.: Testing of a New Drug Against Anaplasmosis (Pfizer T-200)

A. Title Page.

211 (a) Annual Report  
Date due: 1 March 1978  
Date: June 30, 1978

Title: "Expanding Competence in the Design & Execution of Livestock Development Programs in the Tropics, Emphasizing Ruminant Livestock Production Systems Through Improved Breeding & Disease Control" AID/csd-3675

Grantee: Texas A&M University  
College Station, Texas  
One-half to Institute of Tropical Veterinary Medicine,  
College of Veterinary Medicine and  
One-half to Animal Science Department

This one-half of the report is for the Department of  
Animal Science

Grant Program Director: T. C. Cartwright  
AID Sponsoring Technical Office: Development Support Bureau  
(Technical Assistance Bureau)

Statistical Summary:

Period of Grant: 1 July 1972 to 30 June 1977: extended to Dec. 31, 1977.  
Amount of Grant: \$250,000. to the Department of Animal Science

Expenditures:	For 1 July 1976 to 31 Dec. 1977	\$ 52,465.16
	Accumulated, 1 July 1972 to 31 Dec. 1977	\$251,008.06

## B. Narrative Summary

A general cattle production systems model was developed, validated and utilized for simulation. The components included are: nutrition, reproduction and herd components, forage production information in terms of digestibility and crude protein levels and veterinary information in terms of mortality rates of all the various classes of cattle are input. The model is dynamic and adaptable to any geographical area or system of production.

Beef cattle production in the Ebini and Rupununi areas of Guyana were simulated for current production conditions. These simulations of present production were used as additional validations and as baseline values of productivity. The simulation results closely approximated production levels as indicated from data gathered in the area even though the data were not always authoritative or of proven accuracy. Various interventions or production system alternatives were then simulated. Only alternatives which were considered feasible from the standpoint of transportation, capabilities of personnel etc. were considered. For the Ebini area, where beef cattle production has never been a viable activity, although attempted on a number of occasions, a viable production system was worked out through a procedure of examining a number of intuitively determined interventions, discarding or adapting those which did not result in viable production, studying the simulation outputs to determine points of break-down and redesigning the system to overcome the weak points until a viable system was attained.

In the Rupununi area, which is presently the main beef cattle production area of Guyana, various alternative practices were simulated for the purpose of increasing productivity. One alternative system indicated that productivity could be increased by about 25% with only additional input of more intensive care provided by people; the people were available in the area and under-employed.

These results, in addition to being directly useful to the Government of Guyana, demonstrated the utility of the modeling-simulation technique in under developed areas. The data were generated primarily for the purpose of supplying information for use in the sub-sector economic model.

The cattle production systems model was applied to simulation of dual purpose, dairy and beef, herds in lowland northern Colombia. The purpose was to examine the effects of simple, feasible options on total productivity. The optional level of milk taken for sale (vs. that left for the calf), which varied with other variables; the optional size of cow, which coincided closely with present cattle; and the optional milk production potential of cows, balanced with beef production, were examined through simulation. The current production system was quite viable but improvements in amount of food produced and income for producers could be attained with only relatively small changes in management and breeding procedures which were feasible for the people involved.

The most extensive application of the cattle production systems model has been in Botswana in cooperation with the International Livestock Center for Africa and the Botswana Ministry of Agriculture. The major objectives for the systems in Botswana were (1) to design a logical sequence of steps to progress from the traditional production methods to an improved system which has been previously tested, (2) to examine further alternatives for the improved system, (3) to examine the effect of milking cows on beef production, and (4) to provide biotechnical input and output data for use in economic analysis. The initial simulations have been completed and the outcomes published. A second more extensive set of simulations was continued after the termination of this 211(d) grant. The Botswana experience will be used as a base from which to move into the ILCA program in Mali which is technically much more difficult to encompass in a systems analysis study.

### C. Detailed Report:

#### 1. General Background and Description of Problem

The application of improved techniques and methods of ruminant livestock production in developed countries has evolved over a period of time and has usually been based on research conducted within the context of prevailing conditions. The adaptation of these techniques to LDC's has proven to be a complex problem because of the inter-relationships which exists among the various subdisciplines within animal science and because social, economic and climatic constraints not common to developed countries often significantly and unfavorably alter outcome projected on a series of ad hoc considerations. Technical developments within these subdisciplines must be applied within the context of prevailing conditions and with simultaneous consideration of other inter-related effects. A systematic, organized method of examining these effects at the herd level and application of this method to tropical settings is the primary objective of our efforts.

#### 2. Purpose of the Grant

The four universities of the Consortium already had established commitments to agricultural programs in the developing nations. The universities agreed that it was to their advantage, as well as to the benefit of the national foreign assistance program, to cooperate in the development of techniques and methods for research and technical assistance focused on ruminant livestock systems for the wet/dry tropics. To achieve this objective, within the limitations of available resources, they proposed the activities listed below during the five year period.

1. To engage in interdisciplinary and interinstitutional activities. The following are examples of activities which were included:
  - a. To identify viable projects aimed toward understanding management requirements and systems in tropical animal agriculture;

- b. To provide for an interchange of staff among the cooperating universities to develop integrated, functional programs applicable to tropical animal agriculture development;
    - c. To utilize the expertise of visiting scientists from other universities for special requirements;
    - d. To develop collaborative workshop activities in specialized disciplines pertinent to tropical animal agriculture development.
  2. To provide opportunities for education and training of the manpower required for development of the production potential of animals in wet/dry tropics, including:
    - a. Orientation of resident instruction for in-depth training on the characteristics of animal agriculture and forage production in the tropics;
    - b. Establishment of student exchange mechanisms to permit sharing of the strengths of the various institutions and to provide practical experience in the wet/dry tropical environment;
    - c. Development of courses and research techniques in tropical animal agriculture designed to hasten the training and maturity of U.S. and foreign scientists;
    - d. Development of nondegree short courses and training seminars.
  3. To improve the capability to maintain active research on animal agriculture in the wet/dry tropics as a team effort.
    - a. Providing staff with experience and competence necessary for effective training;
    - b. Providing opportunity for student involvement in research as an essential part of training.
  4. To accommodate requests for technical assistance and for consulting services relevant to animal agriculture in the wet/dry tropics; and as considered feasible:
    - a. Release staff for assignments in specialized areas of animal agriculture;
    - b. Assign qualified students for activities that would contribute to their training.
  5. To make available institutional physical resources, including office space, laboratories, equipment, and land for accommodation of activities of:



- a. Resident staff and students;
- b. Exchange staff and students;
- c. Visiting staff and scientists.

### 3. Objectives of the Grant

#### A. Objectives restated

The broad objective of the consortium was to strengthen capabilities through an integrated multidisciplinary approach to:

- a) identify opportunities for significant ruminant livestock production.
- b) analyze constraints to such development.
- c) design programs to overcome constraints and exploit opportunities for developing the ruminant livestock industry.

The objectives for the Animal Science Department at Texas A&M University were to improve competency relating to livestock breeding and selection as a component of livestock production and marketing in LDC's and to develop and evaluate livestock production systems within the constraints and potentials of tropical environments, particularly those of alternating wet and dry seasons at low altitudes. This objective includes the evaluation of different systems which are intuitively designed based on existing knowledge and in consultation with members of the consortium and to identify the major constraints at the herd level to increased production. The Animal Science Department was to develop its capability of teaching undergraduate and graduate students beef cattle production which is directly applicable to tropical LDC's. Adult education was to be included.

#### B. Review of Objectives

The objectives of the Animal Science Department at Texas A&M University were carried out and completed as originally designed. A comprehensive, general, dynamic cattle production systems model was developed, in three major parts, programmed, validated, and applied in LDC locations. The success of the application of the systems model, along with the systems analysis team, is seen in the continued and increasing interest in the application. Application of a general production systems model with input data from the local area (including the forage-feed resource, animal parameters and management procedures) requires a trained, knowledgeable team to adapt the model, choose simulation alternatives and evaluate the output. Although the model is available on request, the large amount of training and experience required for meaningful application was not originally fully recognized.

### C. Review of Critical Assumptions

Since the AID 211(d) grant was to increase competence of the U.S. institutions, no assumptions of a very critical nature regarding conditions outside of grantees' control were necessary. However, in order to gain relevant experience, application in LDC's was necessary. The implied assumption that the Consortium would find suitable locations willing for the Consortium to gain experience through application of a systems approach was not fully met. An objective was for the Consortium to apply a systems approach to a beef cattle production problem in an LDC in Africa. No suitable location was found in Africa. A full and valuable application experience was accomplished in Guyana.

A very critical assumption was that there was sufficient scientific information available on the basic functions of cattle to permit construction of a mathematical model of cattle production systems. Sufficient prior investigation had been accomplished to assure that this assumption could be met at a useful level of detail.

## II. Accomplishments

A. Objective/Output 1. Identify opportunities for significant ruminant livestock production.

1. Narrative description of general output.

Cattle production prevails in almost all areas suitable for production; however, production in LDCs is generally a very inefficient use of the natural and human resources due in large measure to failure or inability to control elements of major importance such as diseases, efficient integration of production components, and marketing. The systems analysis part of the Consortium had the responsibility for developing competence in the area of examining current cattle production systems and designing more efficient feasible alternatives through integrating the various inputs to effectively increase outputs.

The development of a model to simulate beef production under tropical conditions was the major objective of the Animal Science component at Texas A&M University. After over three years of development, the model was put in operation. It was written in FORTRAN and transmitted to Purdue for use with the macro economic model. Validation was completed during the fourth year; the model responded well in simulating real life production as indicated by comparison with intuitive expectations and data of current production in Guyana, Venezuela, Colombia and Botswana.

The model was divided into submodels for the developing process. The submodels are: (1) composition and dynamics of the herd, (2) flow of nutrients, (3) reproduction and (4) economics. A submodel or component on forage production was not developed because the information and time required were lacking. In order to construct a forage model

which would interact with grazing pressure, it appears that at least as much effort would be required as was required to develop the components for nutrition, reproduction and herd composition. The alternative of simply utilizing data on available forage during the span of a year was decided upon. This approach has not compromised the results of the herd production model under stable, or closely definable, forage conditions; it does not allow any prediction of forage response over time such as deteriorating or rejuvenating range.

The model objective is to simulate the production of beef for a defined set of environmental conditions and for given levels of resources. The primary objective of the simulation will be the physical relationships between input-output variables that will allow the economic evaluation as a second step. No interacting veterinary inputs have been considered to date. Presently, intuitive mortality data are utilized. It is anticipated that to add an interacting component which considered disease organisms and parasites as part of the ecological system as they are in real life, just as the forage plants are part of the ecological system, would require an effort similar to that projected for developing an interacting forage component. Again, similar to forage components, effects of veterinary considerations are input in the form of mortality and production coefficients as available or estimated. Simulated mortality is a function of nutritional level but is not truly an interacting component.

The breeding herd composition submodel that describes the dynamics of herd composition makes it possible to predict the age structure of the herd given the initial composition and a set of parameters related to fertility, survival rate and management policy. Decisions such as numbers of animals to be sold, which ones to sell, culling practices, terminal age, etc., can be evaluated by use of this submodel. This submodel is particularly useful in predicting possibilities of cattle population growth for areas to be developed for beef production. The simulation procedure of herd structure has been written so that it is very general and may be used with any set of environmental conditions. However, it will interact with the other parts of the model which will have influence on some of the constants used by this submodel and therefore is a direct function in many ways of the reproduction component.

The nutrient or nutrition submodel describes the use of nutrients of each of the individuals that compose the population; requirements have been defined on a priority sequence according to different biological functions of the individual under consideration. Requirements to fulfill those functions are based on present knowledge and therefore they were computed on the basis of current recommendations. This submodel allows the system to store and withdraw nutrients of the body as a dynamic process. It is designed for use under a wide set of environmental conditions as described below.

B. Objective/Output 2. Analyze constraints to such development (i.e., constraints to production systems; see Objective 1).

The Texas A&M Cattle Production Systems model has been used to simulate production of beef cattle (Sanders, 1966; Cartwright, 1977;

Davis et al., 1976; Ordoñez et al., 1977; and Nelsen et al., 1978a) and dual purpose cattle (Cartwright et al., 1977 and International Livestock Center for Africa, 1978), and, in a revised form, by the United States Meat Animal Research Center (Notter, 1977) to simulate beef cattle production (see appendix for literature citations). These simulations were accomplished for validation purposes and/or for use in LDC on tropical or semitropical forage based production systems.

Sanders (1977) used the model to simulate production of cattle differing widely in genotype for size and milk production under two different sets of Central Texas conditions (environments). These two sets of conditions differed only in the availability of forage. The production systems simulated utilized native forage without supplementation for all classes of animals. Cows calved for the first time as three year olds. Two different breeding seasons were simulated for various genotypes under the two sets of forage conditions. Efficiency was defined as the ratio of total annual sale weight of cattle to total annual dry matter forage consumption, and was calculated for each genotype-environment-breeding season combination. Different genotypes for size and milk production were associated with maximum efficiency under the different environment-breeding season combinations. The efficiency values were assumed to represent net merit and were used in calculations of selection indices.

Cartwright (1977) simulated Central Texas conditions involving different simulated genotypes for size and milk production under both spring and fall calving systems with calves sold either at weaning or after being finished on grain. Some genotypes ranked differently for simulated efficiency under the different management systems.

Davis et al., (1976) used the model to evaluate alternative management strategies in two different regions of Guyana. For both regions, results of simulations of traditional management schemes coincided closely with actual production. After examination of various management changes considered feasible for the area, management schemes were suggested that, based on simulation results, would increase production efficiency in the two different regions and better utilize both the natural and human resources of the areas.

Ordoñez et al., (1977) simulated different times and lengths of breeding seasons and different selling policies for beef production on the western high plains of Venezuela. His results from the model indicated that one of the breeding season alternatives that was simulated offered sufficient increased efficiency to warrant being tested experimentally against the breeding seasons that are currently used in the region.

Nelsen et al., (1978a) simulated production efficiency for cattle differing in genetic potentials for size and milk production under three management systems in Central Texas. Under one management system calves were sold at weaning; in the other systems calves were finished either on native forage or grain. All three systems involved spring calving. Although the efficiency rankings of the different genotypes changes little between systems, the differences in efficiency

between genotypes was different for the different systems.

A modification of the model, which allows the simulation of production systems where cows are milked, was used in the simulations by Cartwright et al., (1977). Production of milk and beef was simulated for three different sets of forage conditions assumed for a locations in Colombia for cattle differing in genetic potentials for size and milk production. By placing relative prices on slaughter animals and milk, rankings for efficiency were evaluated for the various genotypes for size and milk production. This same modification of the model was used for simulating dual purpose production in Botswana (International Livestock Center for Africa, 1978).

Notter (1977) modified the model to allow the simulation of crossbreeding systems and compared the simulated performance of cattle with different genetic potentials in different breeding systems. Some changes in the equations for simulating animal performance were also made; personnel at Texas A&M University and at U.S. Meat Animal Research Center cooperate in minimizing the differences between the models used by the two institutions with regard to the simulation of animal performance.

C. Objective/Output 3. Design programs to overcome constraints and exploit opportunities for developing the ruminant livestock industry.

(See Objective/Output 2 above)

Other areas complementing the research and development relating to systems analysis were development of a course syllabus and textbook for tropical beef production and training of graduate students in tropical beef production systems.

#### Syllabus For Course On Beef Production In The Tropics.

Activity in this area has resulted in an edited manuscript of a text-reference book on tropical beef production. Definite commitments have been made with the Texas A&M University Press to publish the book.

A course on "Beef Production in the Tropics" must of necessity place considerable emphasis on developing an appreciation for and hopefully some understanding of the many and complex problems of the tropical environment, its people, their culture and traditions. The problems are not only climate, but the effect of climate on soils, vegetation, animals and man himself. In addition, the wide variety of tropical environments affected by temperature, rainfall, altitude, prevailing winds and land masses create specific problems peculiar to a given area. The tropical environment is much more varied and complex than is the temperate climate environment.

Animal characteristics which enable them to tolerate the tropical environment with emphasis on the physiology of body temperature regulation must of necessity be stressed. Methods of improving the environment by providing supplemental feed, improving pastures, reducing losses

from parasites and diseases will be included but will vary with the specific environment. Genetic improvement of native cattle by selection, introduction of new stock or by AI offer avenues of progress and are included, with use of examples where such data are available. Surveys of available tropical feed stuffs, and evaluation of native and adaptable introduced forage have been reviewed. Problems of credit, transportation, communication, lack of refrigeration, dietary habits and traditions are discussed. Liberal use is made of visual aids showing climates, soils, vegetation and cattle of the tropics. A substantial reference list has been included.

It is impossible to predict at this time the number of background of students who will be enrolled in this course. The syllabus has now been completed but is updated annually.

### Training

T. T. Voelkel obtained a Master of Science in Animal Science in the area of tropical beef production. He has subsequently been employed on livestock development projects in Botswana and in Mali.

J. O. Sanders has completed M.S. and Ph.D. degrees and is now on the staff as system analyst in Tropical Beef Production.

F. Gomez, National Director of Programs for Beef Cattle, Ministry of Agriculture, Colombia, completed 3 years of Ph.D. training in systems livestock production. His research problem dealt with the use of cows to produce both calves and milk (for human consumption) as is typically done with the majority of cattle in the tropics. He has returned to Colombia and completion of writing up his research is anticipated in 1979.

J. Mallory Davis completed all work toward a Ph.D. except for completing his research in examining alternative beef cattle production systems in northern Brazil and writing the thesis. He was shot and killed while in Brazil collecting further data.

T. S. Stewart completed a Ph.D. degree. His research was in reproductive development and characteristics of tropically adapted and other breeds and crosses.

D. Perotto has completed a Master of Science degree, nonthesis, in the area of tropical beef production. He has returned to Brazil to teach at Univerdisade Federal Rural do Rio de Janeiro.

G. Hawariatt completed an M.S. degree utilizing Small Ruminant data from Ethiopia. He completed the majority of course work, for the Ph.D. by Dec. 1977. His training is being continued by support, as a research assistant, from Texas A&M University System.

T. C. Nelsen completed all course work and research planning for the Ph.D. degree working in systems analysis. He is presently employed by Texas A&M University System as a research associate working in systems analysis.

### III. Impact of Grant Support Activities in Developing Institutional Capabilities

The development of a systems model for beef production in the tropics has had the effect of bringing together the various subdisciplines in Animal Science to provide input information. In the process, a greater appreciation has developed in the staff for the various interactions among the areas of their expertise and the effect of these interactions on production especially as the peculiar qualities of the tropics are imposed along with other constraints common to LDCs. A major problem with live-stock development programs in LDCs is the design for dramatic change rather than a slowly evolving, self-correction, process of change. Under these conditions imbalances are much more prevalent and a systems approach becomes much more useful.

Because of our development in the area of systems beef production, we were invited to present a number of seminars on the topics of systems analysis applied to beef cattle production in both the U.S. and foreign countries.

An agreement with the U.S. Meat Animal Research Center, Clay Center, Nebraska entitled "Simulation of Beef Cattle Production Systems" is a substantial spin-off benefit of this 211(d) grant. The intense beef production problems of the LDCs which are compounded by additional problems of a tropical climate in the past have been almost impossible to bring into focus for application of technology and have forced a more formal, organized consideration of the system. A systems approach to beef production would not likely have developed independently in the U.S. at this time.

This grant has specifically allowed staff to travel to tropical countries to observe, to participate in conferences directed toward tropical livestock production, to develop a comprehensive course specifically on tropical beef production, and to attract students with experience and interest in tropical countries.

### IV. Other Resources For Grant Related Activities

The expertise of the Data Processing Center, Operations Research Group, and Institute of Statistics were necessary for model development. Data from the Texas Agricultural Experiment Station (TAES) were necessary for development and validation. The direction and objectives of the TAES research project entitled "Evaluation Hybrid Systems For Total Efficiency Of Beef Production" were revised in some instances to supply data specifically required for the model development.

The physical facilities including office space and equipment for staff and graduate students, telephones, data processing center, secretarial staff, library, etc., have all been contributed without reimbursement (except for computer time). However, the major contribution has been the availability of the staff of the Animal Science, Agronomy, Range Science and Agricultural Economic Departments for consultation with sponsored graduate students and personnel working on systems model development. For example, it is estimated that personnel

in the ruminant nutrition section annually contributed the equivalent of about 1/2 professional man year to our model development. The animal breeding and genetics section contributed the equivalent of about 1 full professional per year. The reproductive physiology, meats, dairy and management sections of the Animal Science Department have contributed substantial amounts. Operations Research, Range Science and Agricultural Economics also participated in and aided our efforts.

V. Utilization of Institutional Response Capabilities In Development Programs

A. These activities are covered in section and summarized in table III-A and III-B.

B. Graduate students who studied at Texas A&M under the AID 211(d) grant

<u>Name</u>	<u>Citizenship or Country of Residence</u>
T. Voelkel	Botswana, Mali
G. Hawariat	Ethiopia
F. Gomez	Colombia
J. O. Sanders	U.S.
T. Stewart	U.S.
J. Ordonez	Venezuela
C. Tarres	Nicaragua
M. Talamantes	Mexico
A. Garcia	Mexico
J. Martinez	Mexico
D. Perotto	Brazil
M. Davis	Brazil
S. Worjloh	Liberia
T. Nelsen	U.S.
G. Joandet	Argentina

Approximately 25 visitors from LDCs conferred with personnel on the AID 211(d) project during its tenure.

C. Firm, continuing linkages have been established with ILCA and active cooperative work continues in Botswana and is anticipated for Mali and other countries.

D. A title XII project on Small Ruminants has been negotiated to begin in Oct. 1978. A special grant from AID for continuation of use of the Cattle Production Systems Model has been awarded (Aug., 1978).

VI. Involvement of Minority Personnel and Women

One black woman has been involved as a secretary.

There were no problems related to hiring women or minority ethnic group men on this grant and more are anticipated. At last a prorata share are expected to be attracted to continued efforts because of our work with Latin American and African LDCs.



Table I

Distribution of 211(d) Grant Funds and Contributions From Other Sources of Funding\*

Reporting Period 1 July 1972 to 31 Dec. 1977

Grant Objectives/Outputs	Period Under Review	211(d)	Expenditures		Non 211(d) Funding** Amount
		Cumulative Total	Projected Next Year	Projected to end of Grant	
Objective/Output 1. Identify opportunities for significant ruminant livestock production.	NA	50,000	NA	NA	\$ 20,000
Objective/Output 2. Analyze constraints to such developments (i.e., objective/Output 1).	NA	100,000	NA	NA	\$100,000
Objective/Output 3. Design programs to overcome constraints and exploit opportunities for developing the ruminant livestock industry.	NA	101,008	NA	NA	\$100,000

TOTAL

\* These figures are your best estimates

\*\* Include other AID projects if relevant

TABLE IIA

Expenditures for Total Grant Period from 1 July 1972 to 30 June 1977 plus Grant Extension to 31 December 1977  
(Animal Science Department only).

Budget Category	Total Budgeted Amount	Budget Year Expenditures					Total Expenditures
		72-73	73-74	74-75	75-76	76-77 <sup>a</sup>	
Salaries	\$131,500	\$10,431	\$42,885	\$41,229	\$28,682	\$27,077	\$150,304
Graduate Student Assistantships	55,000	4,773	6,300	7,550	8,126	7,800	34,549
Travel and Allowances	40,000	5,409	18,580	3,788	6,213	9,369	43,360
Communication, Library, etc.	1,000	33	215	288	167	343	986
Equipment	5,000	1,245	0	84	0	1,089	2,417
Data Processing and Services and Supplies	17,000	1,006	4,007	3,344	4,248	6,787	19,392
Total	\$250,000	\$22,897	\$71,987	\$56,223	\$47,436	\$52,465	\$251,008

<sup>a</sup> 18 month period from 1 July, 1976 through 31 December, 1977.

Table III - A

Requests For Assistance Received During Reporting Period 1 July 1972 to 31 Dec. 1977

## A. Requests Attended

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort*		Results of Assistance Results of Assistance
				Dollars	Man Days	
Beef Production Development in Guyana	Ministry of Agriculture	Government of Guyana	AID 211(d) grant	70,000	500	Published report of recommended production alternatives for the Ebini and Rupununi areas
Evaluation of Beef Production Constraints in Sabelian Africa	AID Mission in Sabelian countries	AID	AID Mission and AID 211(d) grant	10,000	50	Recommendation for a Range Seminar in U.S. and a Sabelian Conference and production systems
Study of Economic Opportunities for Increased Processing of Beef by Latin American countries	Beef exporting countries of Latin America	Independent study by Texas A&M	AID 211(d) grant	6,000	60	Published report of economic opportunities for reversing beef for export
Survey of Patent rate of Sheep and Goat Production in Botswana	Ministry of Agriculture of Botswana	AID	AID-W and AID 211(d) grant	10,000	60	Report of present status and potentials, both biological and economical
Analysis & Synthesis of Beef Production Systems in Botswana	Botswana Ministry of Agriculture and ILCA	ILCA	ILCA and AID 211(d) grant	50,000	600	Publication of report for transition from traditional production to more efficient production systems

\* Estimates-includes prorata share of cattle production systems model development.

Table III - B

Requests For Assistance Received During Reporting Period 1 July 1972 to 31 Dec. 1977

B. Requests Not Fulfilled

Description of Request for Assistance	Whom did you Assist?	Who Requested Assistance	Who Funded Assistance	Size of Effort		Why not met?
				Dollars	Man Days	
Seminar on Dry Land Range Management for Sabelian Countries		AID				Sabelian Country Ministries of Agriculture could not release participants due to drought emergencies
Conference on Livestock Production Systems for the Sahel		Ministry of Development, Mali				Timing did not permit participation

\* Estimates-includes prorata share of cattle production systems model development.

Appendix I

Publication Resulting From the AID 211(d) Grant

- Cartwright, T. C. 1974. Net effects of genetic variability on beef production systems. *Genetics* 78:541-561.
- Cartwright, T. C. 1975. Principles of selecting and breeding beef cattle for the tropics. Proc. II Ciclo Internacional de Conferencias Sobre Ganaderia, Tampico, Mexico.
- Cartwright, T. C. 1975. Methods and goals for selecting beef cattle with emphasis on the Zebu. Proc. II. Ciclo Internacional de Conferencias Sobre Ganaderia, Tampico, Mexico.
- Cartwright, T. C. 1975. Crossbreeding Systems. In M. E. Ensminger (Ed.) *Beef Cattle Science Handbook* Vol. 12 pp. 50-55. Agriservices Foundation, Clovis, Calif.
- Cartwright, T. C. 1975. Cow Size. In M. E. Ensminger (Ed.) *Beef Cattle Science Handbook*, Vol. 12 pp. 91-95. Agriservices Foundation, Clovis, Calif.
- Cartwright, T. C. 1975. Double muscling in beef cattle. In M. E. Ensminger (Ed.) *Beef Cattle Science Handbook*, Vol. 12 pp. 140-149. Agriservices Foundation, Clovis, Calif.
- Cartwright, T. C. 1975. Uses of modeling cattle breeding systems: Optimization of breeding volumes and optimization of research resources. Proc. Comm. of the European Communities Seminar on Optimization of Cattle Breeding Schemes.
- Cartwright, T. C. 1975. The Use of Modeling To Hasten and Enhance The Application of Research Information To Beef Production Systems And Feedback To Research. *Forage-Fed Beef: Production And Marketing Alternatives In The South*. pp. 451-461. Southern Cooperative Series 220.
- Cartwright, T. C. 1976. Relationships of size, maturing rate, milk production and net lifetime production to productivity. *Beef Cattle Short Course Proc. Tex. Agric. Exp. Sta.*
- Cartwright, T. C. 1977. Potential effects of genetic-environmental interaction on production efficiency, annual report, 5-10 Southern Regional Beef Cattle Breeding.
- Cartwright, T. C. 1978. The use of systems analysis in animal science with emphasis on animal breeding. *J. Animal Sci.* (in press).
- Cartwright, T. C. 1978. Size as a component of beef production efficiency. *J. Animal Sci.* (in press).
- Cartwright, T. C. 1978. The construction and development of animal production systems. Proc. IV. World Conf. on Animal Production.

- Cartwright, T. C. 1978. Cow-calf herd production. *J. Animal Sci.* (in press).
- Cartwright, T. C., Gomez, F. G., Sanders, J. O., & Nelsen, T. C. 1977. Simulated milk-beef production systems in Colombia. *Proceedings American Society of Animal Science Meeting, Madison, Wisconsin* (Abstract).
- Davis, J. M., Cartwright, T. C., & Sanders, J. O. 1976. Alternative Beef Production Systems for Guyana. *J. Anim. Sci.* 43:235 (Abstract).
- International Livestock Center for Africa. 1978. Studies in livestock production systems. Application of a beef cattle production model in Botswana. International Livestock Center For Africa, Addis Ababa, Ethiopia.
- Joandet, G. E. 1974. A model for simulation of beef production. *Proc. NC-1, North Central Regional Beef Cattle Breeding Project.*
- Joandet, G. E. and T. C. Cartwright. 1975. Modelling beef production systems. *J. Animal Sci.* 41:1238-1246.
- Nelsen, T. C., T. C. Cartwright and J. O. Sanders. 1977. Simulated production efficiencies from biologically different cattle in different environments. *Proc. Am. Soc. Animal Sci., Southern Section Matings.* (Abstr.)
- Nelsen, T. C., Cartwright, T. C., & Sanders, J. O. 1978. Simulated production efficiencies from biologically different cattle in different environments. *Proceedings Southern Division American Society of Animal Science Meeting, Houston, Texas* (Abstract).
- Notter, D. R. 1977. Simulated efficiency of beef production for a cow-calf feedlot management system. Ph.D. Dissertation, University of Nebraska, Lincoln, Nebraska.
- Ordóñez, J., Sanders, J. O., & Cartwright, T. C. 1977. Simulación de sistemas de manejo para la producción de carne. VI Reunión ALPA Mem. R13 (Abstr.).
- Sanders, J. O. 1974. A model of reproductive performance in the bovine female. M.S. Thesis, Texas A&M University, College Station, Texas.
- Sanders, J. O. 1977. Application of a beef cattle production model to the evaluation of genetic selection criteria. Ph.D. Dissertation, Texas A&M University, College Station, Texas.
- Sanders, J. O., G. E. Joandet and T. C. Cartwright. 1974. Simulation of female bovine fertility. *J. Animal Sci.* 39:149 (Abstr.).
- Sanders, J. O. and T. C. Cartwright. 1976. Simulation of reproductive performance of cow and heifers. *Texas Agric. Exp. Station, Beef Cattle Research In Texas.* P.R. 3383C pp. 86-103.

Sanders, J. O. & Cartwright, T. C. 1978. A general cattle production systems model. II. Simulation of Animal Performance. Agricultural Systems. (Submitted).

Sanders, J. O. & Cartwright, T. C. 1978. A general cattle production systems model. I. Description of the model. Agricultural Systems. (Submitted).

APPENDIX II

Seminars presented as part of the AID 211(d) Grant program on Ruminant Livestock Production Systems in the Tropics.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding and Genetics Seminar  
Tuesday 12:00 Noon, November 21, 1972  
Room 203 Animal Industries Building

"GENETIC IMPROVEMENT OF SHEEP UNDER SEMI-ARID CONDITIONS

Dr. E. Salah E. Galal  
Assistant Professor of Animal Breeding  
Ain Shans University, Egypt

Dr. Galal earned his B.S. degree in Agriculture at Alexandria University, his M.S. in Animal Breeding at Texas A&M, and his Ph.D. in Animal Breeding at Iowa State. After receiving his Ph.D. in 1965, he returned to Egypt to a research position at the Desert Institute to work in the field of sheep breeding. At present he is on sabbatical leave teaching statistics at the University of West Virginia.

Dr. Galal has published fourteen research papers and written a book on animal breeding in Arabic. Many will remember Dr. Galal at Texas A&M as an outstanding student and for his cheery personality - he is a good ambassador for his country. His seminar will be of direct interest to those concerned with sheep breeding or semi-arid animal production and to those in animal breeding. Also, it will be of interest to those concerned with research in less developed and semi-arid tropical areas.

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ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SEMINAR

A series of two seminars on Tropical beef production is announced.

BALI CATTLE - AN ACCOUNT AND CRITIQUE OF THE BREED"

4:00 p.m. Thursday

December 14, 1972

Room 203 Animal Industries Building.

PROBLEMS OF AND POSSIBILITIES FOR CATTLE PRODUCTION IN AFRICA'

12:00 Noon Friday

December 15, 1972

Room 203 Animal Industries Building

by

Dr. W.J.A. Payne  
Visiting Professor  
University of Florida  
Gainesville, Florida

Dr. W.J.A. Payne is presently Visiting Professor at the University of Florida teaching graduate courses and advising on beef production in tropical areas. Dr. Payne has had extensive experience in Southeast Asia, Africa and the Philippines and is author of the book 'Cattle Production In The Tropics. He is co-author of An Introduction To Animal Husbandry In The Tropics.

ANIMAL SCIENCE DEPARTMENT  
ANIMAL BREEDING AND GENETICS SEMINAR  
ON  
TROPICAL BEEF PRODUCTION

CROSSBREEDING IN TROPICAL VENEZUELA AND BOLIVIA

3:30 p.m. Monday

July 2, 1973

Room 203 Animal Industries Bldg.

by

Dr. Dieter Plasse

Professor, Veterinary Science Faculty

(Leader, Genetics Group)

Central University of Venezuela

Maracay, Venezuela

Dr. Plasse did his undergraduate and masters work at the Animal Breeding Institute, University of Göttingen under Prof. Fritz Mating. He then worked toward his Ph.D. degree doing his research with Prof. Marvin Koger at the University of Florida. Dr. Plasse has been very active in Venezuela in organizing and carrying out beef cattle breeding research. Most people in animal science are familiar with the fact that he has numerous publications in English and Spanish.

Dr. Plasse has made an enviable record of accomplishment in Venezuela in a relatively short time establishing a reputation as a scientist. At the same time he has gained the reputation for being practical and developing information and recommendations immediately applicable.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding and Genetics Seminar  
Wednesday 12:00 Noon, November 8, 1972  
Room 203 Animal Industries Building

BEEF CATTLE RESEARCH IN LOW RAINFALL AREAS OF RHODESIA

by

Dr. J.D.G. Steenkamp  
Matopos Research Station  
Bulawayo, Rhodesia

Dr. Steenkamp is Principal Research Officer at the Matopos Research Station which is the center for beef cattle production research in Rhodesia. Of particular interest to some of us is his research with genetic x environment interaction and the response of cow efficiency of small and large cows over time with selection. Dr. Steenkamp will give a general presentation of research at the Matopos Station and topics of particular interest can be followed with questions.

ANIMAL SCIENCE DEPARTMENT  
ANIMAL BREEDING AND GENETICS SEMINAR  
ON  
TROPICAL BEEF PRODUCTION

CROSSBREEDING IN TROPICAL VENEZUELA AND BOLIVIA

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ANIMAL SCIENCE DEPARTMENT

SEMINAR

Animal Breeding and Genetics Section

12:00 Noon

Friday, September 14, 1973

Room 203 AI Building

"A DYNAMIC BEEF CATTLE HERD MODEL"

by

Joe Humber and Guillermo E. Joandet

Population geneticists have long recognized that a population has genetic characteristics which can not be imputed from the separate characteristics of the individual members of the population. However, they have not generally recognized the corollary that population (or herd) production characteristics can not be inferred from the characteristics of its isolated members. One reason for this failure certainly must have been the imposing nature of the task of accounting for all the interacting components affecting production particularly as it relates to efficiency. The techniques of operations research and the capacity of electronic computers have now made it feasible to model herd production. Joe Humber has brought expertise in operations research and "Willy" Joandet has directed the constructing of a beef herd model which they will describe.

Those in nutrition, physiology, beef production, and economics, will be as interested as those in genetics in learning about the values and methods used in constructing the model. Perhaps those in Extension will have even more interest in its potential use for formulating realistic recommendations.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, October 5, 1973

Room 203 AI Building

"THE RELATIONSHIP BETWEEN SIZE AND PRODUCTION EFFICIENCY  
OF AFRICANDER CATTLE IN RHODESIA"

by

Dr. Johan Steenkamp

Dr. Steenkamp is Principal Research Officer at the Matapos Research Station, Bulawayo, Rhodesia. At present he is spending 4 months leave as Research Scientist consulting with the Tropical Beef Production project of the Animal Science Department. In addition to consulting, Dr. Steenkamp has brought along data he has collected over a number of years on Africander cattle supplemented at different nutritional levels. These data will be further analyzed here and used to validation test of a system production model. Dr. Steenkamp has collected a wealth of data under closely controlled conditions which will add to our knowledge of methods to increase production efficiency. One question for which these data are useful in answering is that of the effect cow size on production efficiency.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, December 14, 1973

Room 203 AI Building

"CURRENT RESEARCH IN CATTLE BREEDING IN IRELAND"

by

Dr. E.P. Cunningham

Many of you are familiar with Dr. Cunningham's publications. All animal breeding major's are familiar with his book Animal Breeding Theory published in 1969. Dr. Cunningham is with The Agricultural Institute, Animal Production Research Centre, Dublin.

In addition to an overview, he will speak more specifically to the topic of "cost effectiveness" of beef and dairy production - a topic which will especially appeal to those in production and to the modelers.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, February 22, 1974

Room 203 AI Building

"BEEF PRODUCTION IN COLOMBIA"

by

Fernando Gomez

A description of the existing situation in Colombia regarding beef production and potentials for change as well as action being taken to bring about these changes. The role of research in this activity will be discussed.



OFFICE OF ANIMAL SCIENCE  
TEAGUE RESEARCH CENTER  
BY

MR. R. W. (DICK) RICE  
DEPARTMENT OF ANIMAL SCIENCE  
UNIVERSITY OF WYOMING

SUBJECT MATTER:

SIMULATION OF ANIMAL FUNCTIONS  
IN MODELS OF PRODUCTION SYSTEMS:  
RUMINANTS ON THE RANGE

TIME: JULY 1, 1974 - 3:00 PM

LOCATION: ROOM 118, TEAGUE RESEARCH CENTER

ALL INTERESTED FACULTY AND STUDENTS  
ARE URGED TO ATTEND!!

\*\*\*\*\*

!!!!!!ROUNDTABLE DISCUSSION!!!!!!

on

INTERNATIONAL DEVELOPMENT

Dr. Thomas Cartwright, Animal Science Dept.

"The Effect of the Drought on the  
Livestock Industry in the Sahel"

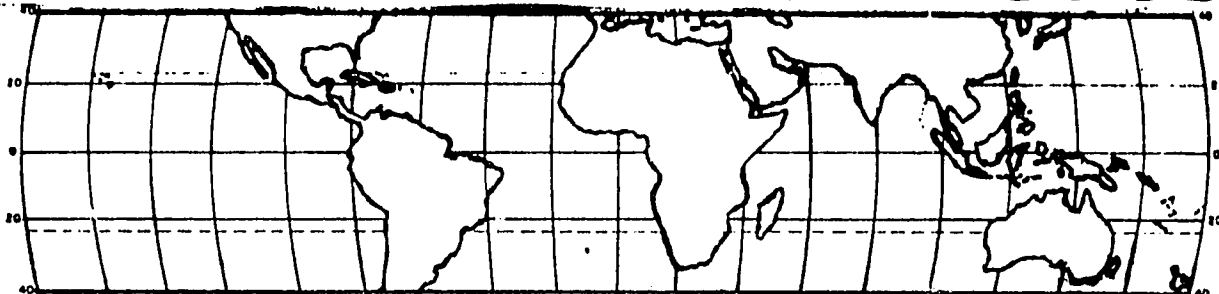
Agriculture Building, Room 300

Tuesday, July 23rd

NOON

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# EXPERIENCE THE TROPICS



**DR. T.C. CARTWRIGHT (ANIMAL SCIENCE)**

**&**

**DR. R. STELLY (AGR. ECO.)**

WILL GIVE AN ILLUSTRATED TALK CONCERNING THEIR RECENT  
JOURNEYS TO AFRICA

**"PROBLEMS IN THE SAHEL"**

THIS IS THE FOURTH IN THE EVENING SERIES ARRANGED  
BY THE

TROPICAL STUDIES PROGRAM  
GEOGRAPHY DEPARTMENT

TIME 7:30 P.M.

TUESDAY

MARCH 25, 1975

RM. 510 J. EARL RUDDER CENTER

COFFEE WILL BE SERVED AFTER THE TALK.

THE PUBLIC IS INVITED.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, April 18, 1975

Room 203 AI Building

"RECENT DEVELOPMENTS IN DAIRY SIRE EVALUATION"

by

Fernando Gomez

The techniques used in the widespread progeny testing of dairy sires represents a high level of refinement in applied animal breeding. The concepts employed as well as the techniques and results should be of interest to all concerned with improvement of livestock.

ANIMAL SCIENCE DEPARTMENT

"THE CATTLE REPRODUCTION RESEARCH PROGRAM AT MARC"

Thursday, July 18, 1974

12:00 Noon

Room 203 A.I. Bldg.

by

Dr. Dan Laster

Research Leader, Reproductive Physiology

U.S. Meat Animal Research Center

Clay Center, Nebraska

Recently TAES and the U.S. Meat Animal Research Center signed an agreement to enter into a joint effort entitled "Simulation Of Beef Cattle Production Systems." This agreement calls for personnel of each organization to confer and collaborate on model development. Dr. Laster's trip to TAMU is the first of these exchanges for the purpose of conferring on model development since the agreement was signed. His particular interest will be in the reproductive component of the model in its present state and planned revisions.

Dr. Laster received the B.S. degree from the University of Tennessee, the M.S. from the University of Kentucky and the Ph.D. from Oklahoma State University in Reproductive Physiology. He was an NIH Post doctoral Fellow at Iowa State University in reproductive endocrinology and then a member of the Animal Science staff at Iowa State. He has been on the staff of the U.S. Meat Animal Research Center since 1971. Dr. Laster's research has included the study of multiple ovulation in cattle, examination of effects of exogenous hormones, characterization of reproductive abilities of several breeds and types of cattle and sheep, and determination of the effects of dystocia and early weaning on reproduction in cattle.

Dr. Laster's visit provides an excellent opportunity to learn more about the extensive reproduction research at MARC where there are now six reproductive physiologists in residence. Also, some may wish to confer individually with Dr. Laster.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

1:00 P.M.

Tuesday, November 5, 1974

Room 203 AI Building

FUTURE TRENDS IN BODY COMPOSITION RESEARCH

by

Dr. Roger Seebeck  
CSIRO Division of  
Animal Genetics Cattle Research Laboratory  
Rockhampton, Queensland, Australia

Dr. Seebeck did his doctoral graduate work at the University of Melbourne on growth and development of farm animals and has continued research in this field. He is presently on a tour of a number of research institutions on his way back to Australia after a sabbatical year in France. He will be at Texas A&M Monday and Tuesday October 4 and 5, 1974 and has agreed to present a seminar. Those of us interested in research concerned with body composition are indeed fortunate to have this opportunity to have Dr. Seebeck, an authority particularly on design and analysis, on campus. (All animal breeding students are given the assignment to review the following article before the seminar: Seebeck, R.M. 1968. Developmental studies of body composition. Animal Breeding Abstracts 36:167-181. This is an invited review article; copies are in 319 AI, T.C.C.)

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, May 2, 1975

Room 203 AI Building

"ECONOMIC AND BIOLOGICAL RETURNS TO BEEF PRODUCTION  
USING THE GUELPH LINEAR PROGRAMMING MODEL"

by

Dr. C. A. Morris

Dr. Chris Morris is a professor in the Department of Animal and Poultry Science, Ontario Agricultural College, Guelph, Ontario.

Dr. Morris and colleagues have been actively engaged in simulating beef production for some time and have now generated considerable output. In the process of developing the production model, various subdisciplines have contributed. Dr. Morris indicated cooperating nutritionist, especially, have contributed much to the understanding of nutrient requirements for milk production and calf growth.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

11:00 A.M.

Thursday, September 12, 1974

Room 203 AI Building

"GRASSLAND BEEF PRODUCTION IN THE HUMID TROPICS"

by

Dr. A.W. Qureshi

Dr. Qureshi has a B. Vet. Sci. degree from Osmania University and the M.S. and Ph.D. degrees in Animal Breeding from Texas A&M. He has served as Extension and Research Officer in Pakistan, Research Associate at Iowa State and Head, Department of Animal Breeding at the Agriculture University, Lyallpur Pakistan. Since 1964 he has been Animal Production Officer and Team Leader, successively, with FAO/UNDP in Uganda. At present he is on leave from FAO spending his accumulated annual leave time working with the AID 211(d) Tropical Beef Production program at Texas A&M.

Dr. Qureshi's high level of training and expertise reinforced with wide experience in tropical areas combines an unusual and valuable set of characteristics especially useful for advising on the Tropical Beef Production program.



ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

11:00 A.M.

Thursday, September 26, 1974

Room 203 AI Building

"ANIMAL BREEDING APPLIED TO THE SAHELIAN REGION OF AFRICA"

by

T.C. Cartwright

Dr. Cartwright spent several weeks early this summer in the area which is the southern border of the Sahara. This large land area has very limited resources other than its people and its cattle. A question which has been seriously asked is whether this area should be (a) abandoned by people, (b) returned to limited utilization by nomadic cattle tribes, (c) or "developed" to support the maximum number of people. A more limited question is what role, if any, can animal breeding play at least in alternative (c)? Other, still more limited questions, might be posed. Of what value might the "breeds" of cattle found in the Sahel be to other tropical areas? What are the genetic differences among these "breeds" in their resistance to trypanosomiasis and how is the resistance mediated?

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SEMINAR

11:00 A.M.

Thursday, September 19, 1974

Room 203 AI Building

"PRE- AND POST- ANALYSIS OF SELECTION RESULTS IN BEEF CATTLE"

by

Terry S. Stewart

"The phenotypic and genetic relationships existing between and within traits used as criteria for selection in beef cattle must be known to maximize the rate of progress in a selection program and to devise the most efficient breeding plans." Shelby 1965.

"Animal Geneticist have been ready to support national livestock improvement schemes, without any efficient means of assessing their worth in practice." Smith 1962.

Terry Stewart completed his M.S. degree in Animal Breeding at Florida before coming here. His seminar will be based on his M.S. thesis.

The seminar originally planned will be given at a later date.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, January 31, 1975

Room 203 AI Building

"ECONOMIC EVALUATION OF HETEROSIS"

by

Fernando Gomez

Fernando Gomez, a native of Colombia, has an M.S. from Oregon State and is presently working toward a Ph.D. in Animal Breeding. He is on leave from his position as Director of the National Beef Cattle Program of the Instituto Colombiano Agropecuario. He is presently a fellow in the Tropical Livestock Production program. His special interest is in dual purpose of crossbreeding cattle in tropical areas. It has been estimated that one-half of the cows of the world are both milked and suckled in tropical or sub-tropical areas. This seminar will be a general treatment of the subject using cattle for examples.

NOTICE OF A SPECIAL SEMINAR  
TO BE PRESENTED  
BY

DR. R. W. (DICK) RICE  
DEPARTMENT OF ANIMAL SCIENCE  
UNIVERSITY OF WYOMING

SUBJECT MATTER:

SIMULATION OF ANIMAL FUNCTIONS  
IN MODELS OF PRODUCTION SYSTEMS:  
RUMINANTS ON THE RANGE

TIME: JULY 1, 1974 - 3:00 PM

LOCATION: ROOM 118, TEAGUE RESEARCH CENTER

ALL INTERESTED FACULTY AND STUDENTS  
ARE URGED TO ATTEND!!

## EXPERIENCE THE TROPICS

DR. A. W. QURESHI, PROJECT MANAGER, F.A.O.  
BEEF DEVELOPMENT PROJECT, UGANDA, WILL  
PRESENT AN ILLUSTRATED PROGRAM ENTITLED

### *GRASSLAND ECOLOGY AND RANCH DEVELOPMENT IN UGANDA, EAST AFRICA*

This is the first in the 2nd evening series arranged by the  
TROPICAL STUDIES OFFICE  
GEOGRAPHY DEPARTMENT

TIME - 7 : 30 P.M., TUESDAY, OCTOBER 15, 1974

PLACE - RM. 302 J. EARL RUDDER CENTER

COFFEE WILL BE SERVED AFTER THE TALK  
THE PUBLIC IS INVITED

ANIMAL SCIENCE DEPARTMENT

SEMINAR

Thursday

June 19, 1975

3:30 p.m.

Room 317 AI Building

"AN EXAMINATION OF THE RELATIVE EFFICIENCY OF CATTLE WITH A HIGH PRODUCTION POTENTIAL vs. CATTLE WITH A LOWER PRODUCTION POTENTIAL UNDER CONDITIONS OF LIMITED AVAILABILITY OF NUTRIENTS"

by

Dr. G. E. Joandet

Dr. Joandet is well-known to you as he was a Visiting Professor here during 1973-74 working on simulation of beef cattle production systems. He has just attended a conference in Panama on agricultural research in Latin America and is returning to Argentina via College Station. We are fortunate to have Dr. Joandet here and to have him present this seminar. In addition he will discuss the results of the carcass and meats research conducted in connection with the beef cattle crossbreeding project at Balcarce. This discussion is scheduled at the night Journal Club meeting on Tuesday, June 17, 8:30 p.m., Dr. Charles Long's house.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, March 7, 1975

Room 203 AI Building

- I. Comments On Cattle Breeding In Some Eastern European Countries
- II. A New Research Project Proposal Entitled:  
"Simulation Of Forage Based Beef Cattle  
Production Systems To Evaluate Biological  
Efficiency And Economic Viability"
- III. Selection Limits As A Function Of Fecundity.

by

T.C. Cartwright

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, September 19, 1975

Room 115 AI Building

"DETECTION OF BISON BREEDING IN CROSSBREDS"

by

Dr. Jerry Caldwell

Dr. Caldwell will discuss application of research in Immunogenetics to the resolution of disputes regarding Bison breeding in crosses and possible estimation of percentage Bison breeding in crosses.



ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, September 12, 1975

Room 115 AI Building

"OBSERVATIONS ON THE VENEZUELAN BEEF CATTLE INDUSTRY"

by

Jorge Ordonez

Jorge Ordonez, a Ph.D. student in Animal Breeding, recently returned from a visit to his home country, Venezuela. On his trip, he visited several commercial herds which are performance testing. His slide presentation and discussion should be interesting to many.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, October 3, 1975

Room 115 AI Building

"PROMISING AREAS FOR EXPANSION AND  
INTENSIFICATION OF BEEF PRODUCTION"

by

Mallory Davis

Mallory will present his thoughts on land resources which may be used for beef production in the future. He will discuss the technology which he feels is needed to support this expansion.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, October 24, 1975

Room 115 AI Building

"A SAFARI IN UGANDA"

by

T. C. Cartwright

Uganda is considered by many people to be the most attractive country in Africa - the pearl of Africa - from the standpoint of natural resources and beauty. Cartwright recently spent a few weeks of his annual leave in Uganda as leader of a six-man team with the mission to write a beef and dairy development project for the country. He will show slides of several types of indigenous Ugandan cattle and comment on beef cattle production systems in Uganda. The development project includes the work of Mike Callahan, a recent Master of Agriculture, Feedlot Management, graduate who many of you will remember.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

4:00 P.M.

Tuesday December 2, 1975

Room 317 AI Bldg.

"SOME ASPECTS OF BIOMATHEMATICAL MODELING"

by

Dr. H. I. Lucas

Dr. "Curly" Lucas is Director of the Biomathematics Program of the Statistics Department of North Carolina State University. He is well known, at least by reputation, to many of us in Agricultural research utilizing quantitative methods through his contribution to statistics and biomathematics. He has been especially active in consulting with the "TAES Forage Group".

We feel especially fortunate to have Dr. Lucas here to review and critique our latest beef cattle herd production model which has reached the first stage of completion. His topic will be related to this modeling effort.

Dr. Lucas will also meet with the "TAES Forage Group" December 3 and 4 to advice on design of their research projects.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

12:00 Noon

Friday January 23, 1976

Room 115 AI Bldg.

"SUMMARY OF THE BEEF CATTLE REPRODUCTION AND BREEDING PAPERS  
PRESENTED AT THE 1975 ALPA MEETINGS"

BY

Jorge Ordoñez

ALPA is the Asociacion Latinoamericana de Produccion Animal and is the Latin American counterpart of ASAS. The 1975 meetings were held in Caracas, Venezuela. The Memoria, Proceedings, are published in Spanish and not easily interpretable by most of us. We are fortunate to have Jorge Ordoñez, who attended the meetings, to review the papers he considers are most relevant to our interests.

Also at this first meeting we will discuss meeting time and place for the rest of the semester.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

12:00 Noon

Friday February 13, 1976

Room 115 AI Bldg.

"OBSERVATIONS ON SHEEP AND SHEEP BREEDING IN RUSSIA"

by

Dr. Maurice Shelton

Dr. Shelton, Professor, Animal Science Department is stationed at the Texas A&M University Agricultural Research And Extension Center at San Angelo. He is recognized as an outstanding animal breeder, specializing in sheep and goats, among both research scientists and producers. He is especially noted for his lucid analysis of seemingly complex problems and his straightforward approach.

Dr. Shelton's seminar will be based on a recent trip to U.S.S.R. with stops in Ireland and Iceland.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, March 5, 1976

Room 115 AI Building

"THE USE OF SYSTEMS ANALYSIS FOR EVALUATING  
ALTERNATIVE PRODUCTION PRACTICES IN GUYANA"

by

T. C. Cartwright and J. Mallory Davis

The speakers will have just returned from presenting a report of the results of simulated beef cattle production systems in Guyana. This method has given insight into some production barriers which have existed and had aided in identifying some alternatives which will (and some which will not) overcome the production constraints.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, March 26, 1976

Room 115 AI Building

"A PROPOSED TECHNIQUE FOR DETECTING BISON BREEDING IN QUESTIONABLE BISON-CATTLE  
HYBRIDS BY USE OF MORPHOLOGICAL CHARACTERISTICS OF THE HAIR"

BY

Mark Shifrin

As you know, there is a great amount of interest in validating the presence of Bison breeding in individuals reputed to be Bison-Cattle hybrids but which do not clearly exhibit convincing conformation and color characteristics. The Immunogenetics Laboratory can attest to this interest by the number of letters, inquiries and requests they have received during the past year. This interest has led lab personnel into devising techniques to augment the established blood typing which is not sufficiently discriminating at least at this point. Mark, a graduate student in Immunogenetics, will bring us up-to-date on these activities and especially his work with the hair samples.



ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, April 2, 1976

Room 115 AI Building

"SOME FACTORS RELATED WITH POSTPARTUM  
REPRODUCTION OF GYR AND BRAHMAN COWS"

by

Dario Montoni

Mr. Montoni will report on the results of his research conducted with Gyr at the Pariaguán Experiment Station, Anzátequi Station, Venezuela. Also he will present his thesis proposal and results to data for similar research with Brahman at Texas A&M.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, April 23, 1976

Room 115 AI Building

RESULTS OF RESEARCH WITH ZEBU CATTLE IN BRAZIL"

by

Daniel Perotto

Zebu or Bos indicus cattle are widely used in Brazil similar to the use of Brahman cattle in the Southern United States. However, in Brazil the Zebu is much more prevalent and the original strains from India have been kept separate as well combined into a synthetic in a manner similar to that followed in establishing the Brahman. Considerable research has been conducted with Zebu in Brazil but the results have not been readily available to us because many of the reports are published only in Portuguese. These reports include results from both crossbreeding and straight-breeding.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

Tuesday, May 25, 1976

2:00 PM

Room 317 Animal Industries Building

THE EFFECT OF SOAKING OF COMPLETE FATTENING RATIONS ON  
PERFORMANCE AND FAT DEPOSITION OF HOLSTEIN BULLS IN ISRAEL

by

Dr. David Levy

Dr. Levy is in charge of beef cattle research at the Newe Yaar Regional Experiment Station near Haifa, Israel. He has a number of publications dealing with compensatory growth, behavior of bulls in the feedlot, feed conversion, use of chicken litter and related topics. His latest research has led to some unexpected and interesting results which he will present in the seminar scheduled above.

ANIMAL SCIENCE DEPARTMENT  
Animal Breeding and Genetics Section  
SEMINAR  
Friday  
October 22, 1976  
3:30 p.m.  
Room 317  
Animal Industries Building

The Use Of Local Cattle And Sheep Populations And  
Genetic Improvement Systems For Difficult Environ-  
ments And Extensive Husbandry Conditions In The  
Mediterranean Basin And South Africa

by

Dr. Jan G. Boyazoglu  
South African Counsellor on Technical  
and Scientific Matters For Europe

Dr. Bogazoglu received his formal training in animal breeding at the University of Pretoria, South Africa and in economics in France. He was a research scientist and proceeded up the ladder to Director of Agricultural Technical Services, Ministry of Agriculture, South Africa. Presently he is stationed in Paris to represent South Africa in Europe on international agricultural. He has been a prolific contributor to scientific journals; a number of his articles share authorship with French geneticists who have been previous speakers at our seminars: Vissac, Minnissier and Lauvergne. Most of his publications have been related to genetics and animal breeding, but he has also written popular articles and reports on such topics as the "world beef crisis".

Dr. Boyazoglu's reputation as an interesting and knowledgeable speaker precedes him as relayed through our colleagues in France, South Africa and the U.S. His talk will be of general interest and illustrated with slides.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding And Genetics Section

SEMINAR

April 29, 1977

12:00 Noon

Room 115

Animal Industries Building

BEEF PRODUCTION IN THE HUASTECAS REGION  
"GULF COASTAL PLAIN OF MEXICO"

by

Andres Garcia

Andres Garcia has worked with Dr. Jorge de Alba in the Huastecas region of Mexico. He will present a description of the livestock industry and beef cattle production systems utilized in this region. Also he will present a summary of animal data from a grazing trial conducted at the Mexican Association of Animal Production training center in the Gulf Coast of Mexico.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

April 22, 1977

Room 115

Animal Industries Building

DAIRY PRODUCTION IN THE TROPICS

by

Mr. Ricardo Contreras

Mr. Contreras will present data on milk production by crossbred cows involving the Holstein, Brown Swiss, Criollo, Brahman and other Zebu breeds. These data were collected in the state of Zulia in Venezuela; climate at this location is tropical. In addition, Mr. Contreras will present an overview of dairy production in the tropics. The discussion should prove of interest to those concerned with environmental effects on livestock production and tailoring breeding programs to meet adverse environmental conditions.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

April 15, 1977

12:00 a.m.

Room 115

Animal Industries Building

SOME FACTORS AFFECTING FERTILITY AND RATE  
OF GROWTH IN TROPICAL LATIN AMERICA

by

Mr. Justo Gonzales

Mr. Gonzales has reviewed work conducted in tropical Latin America countries which deals with the characters related to fertility and growth in cattle. He will discuss these reports. Since most of these results are published in non-English journals, this is an opportunity to learn about these studies in a rather easy manner. Fertility and growth characters are closely related to beef production efficiency. All who work with beef production should benefit from the discussion and review of these reports.

NOTICE

SPECIAL SEMINAR - TODAY

Room 317 A.I.

4:00 p.m. Thursday, September 2, 1976

BEEF CATTLE PRODUCTION AND DEVELOPMENT IN AFRICA

by

Dr. Georges Tacher

Dr. Tacher is presently Associate Director of the International Livestock Center for Africa (ILCA) headquartered in Addis Ababa, Etheopia. He has had much experience in Africa and his seminar should be interesting and informative.



ANIMAL SCIENCE DEPARTMENT

Animal Breeding and Genetics Section

SEMINAR

Tuesday

December 7, 1976

4:00 p.m.

Room 317

Animal Industries Building

Growth Characteristics Of Crosses Among Indigenous  
Zebu And Bos Taurus Dairy Breeds In Ethiopia

by

Girma Harwariat  
Graduate Student  
Animal Breeding Section  
Animal Science Department  
Texas A&M University

Mr. Harwariat has analyzed data from the Institute Of Agricultural Research in Ethiopia for his M.S. thesis. These data were taken from  $F_1$  calves sired by Simmental, Holstein and Jersey breeds out of Zebu cows of two native breeds and one imported breed (Boran). The data were collected at four stations and include weights from birth up to a year of age.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding and Genetics Section

SEMINAR

Tuesday

November 30, 1976

4:00 p.m.

Room 317

Animal Industries Building

An Examination Of Management Alternatives To Maximize  
Beef Production Of The Western High Plains Of Venezuela

by

Jorge Ordonez  
Graduate Student  
Animal Breeding Section  
Animal Science Department  
Texas A&M University

Mr. Ordonez is on leave from The Faculty Of Veterinary Sciences, Central University Of Venezuela at Maracay. His Ph.D. research will involve an analysis of very extensive data he has collected on beef cattle production characters from ranches in Venezuela. This seminar will be a report of simulation results utilizing parameters from Venezuela. Data Ordonez has collected form an excellent base for validation of the models used for the simulations. These simulations provide an insight into the effects of altering management practices for these specific conditions.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding and Genetics Section

SEMINAR

Tuesday

November 23, 1976

4:00 p.m.

Room 317

Animal Industries Building

SELECTION FOR GROWTH OF CATTLE UNDER A STRESSFUL ENVIRONMENT

by

Mr. John E. Frisch

Experimental Officer

Division Of Animal Production, Tropical Research Center  
C.S.I.R.O., Rockhampton, Queensland, Australia

Mr. Frisch is located at the National Cattle Breeding Station, referred to as Belmont, which is located in tropical Australia. The European breeds involved in the research at this station are Hereford and Shorthorn. The Zebu breeds are Africander, Brahman and Sahiwal. The research at this station involves crossbreeding and has produced the Belmont Red breed.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding And Genetics Section

SEMINAR

April 29, 1977

12:00 Noon

Room 115

Animal Industries Building

BEEF PRODUCTION IN THE HUASTECAS REGION  
"GULF COASTAL PLAIN OF MEXICO"

by

Andres Garcia

Andres Garcia has worked with Dr. Jorge de Alba in the Huastecas region of Mexico. He will present a description of the livestock industry and beef cattle production systems utilized in this region. Also he will present a summary of animal data from a grazing trial conducted at the Mexican Association of Animal Production training center in the Gulf Coast of Mexico.

ANIMAL SCIENCE DEPARTMENT

Animal Breeding And Genetics Section

SEMINAR

PRODUCTIVITY OF SOME INDIGENOUS CATTLE BREEDS OF AFRICA

Dr. John Trail  
International Livestock Center For Africa  
Addis Ababa, Ethiopia

11:00 A.M., Friday, October 14, 1977

Room 133

Animal Industries Building

Dr. Trail is a native of Scotland with a Ph.D. degree in Animal Breeding from the University of Edinburgh. He has quite extensive experience in Africa cattle production working in Uganda and Botswana before joining ILCA in Addis Ababa. He has recently moved to Nairobi, Kenya along with a systems analysis team from ILCA with present commitments to conduct studies in Botswana and Mali. Dr. Trail and Dr. Frank Anderson, an agricultural economist also with ILCA, are at Texas A&M for the purpose of studying the Texas A&M Beef Cattle Simulation Model. The Animal Breeding Section will cooperate with ILCA in applying this model to the cattle production studies in Botswana and Mali.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

SELECTION FOR REPRODUCTION RATE

Dr. Helen Newton Turner

C.S.I.R.O., Epping, New South Wales, Australia

11:00 a.m. Friday

November 19, 1976

Room 115 Animal Industries Bldg.

Dr. Turner is known around the world for her contributions to quantitative genetics and to sheep breeding. Perhaps her best known publication is the book Quantitative Genetics In Sheep Breeding co-authored by S.S.Y. Young.

Dr. Turner is participating in a conference on small ruminants at the Winrock International Livestock Center November 15-17 and has agreed to come by Texas A&M University on her way back to Australia. In addition to the seminar, there will be an informal discussion of the sheep industry, sheep breeding and development of systems analysis in Australia Thursday evening at 7:30 at 211 Lee Street, College Station. Everyone interested is invited.

Dr. Turner's seminar should be of general interest and especially interesting to those in sheep, reproduction and animal breeding.

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

DESCRIPTION OF A PARTIALLY INTERGRATED BEEF SUPPLY OPERATION

by

Dr. George Ellis  
Cattle Development Corporation  
Gruver, Texas

4:00 PM

Monday, April 24, 1978  
Room 400 Kleberg Center

Dr. Ellis is on campus for the day and has agreed to present an informal seminar on the Cattle Development Corporation (a subsidiary of Keystone Food, Inc.) operation extending from purchase of feeders through wholesaling a prefabricated product to McDonalds. This seminar should be interesting to anyone concerned with the beef cattle industry and provide some insight into present and indicated future trends.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

4:00 P.M.

May 22, 1978

Room 400

Kleberg Center

Cattle Production And Land Improvement In Northeastern Argentina  
by  
Hernan Pueyrredon

A slide presentation and discussion of agricultural and Livestock practices in Northeastern Argentina with special references to the province of Formosa will be conducted by Mr. Pueyrredon. Conclusions related to the special environmental conditions, forage and cattle production will be emphasized.



ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

12:00 NOON

April 28, 1978

Room 400

Kleberg Center

Dairy Performance Under Tropical Conditions

by

Leonardo Nieves

Brown Swiss x Criollo cross cows were evaluated for milk yield and reproduction under tropical conditions in Venezuela. Data were analyzed to yield estimates of effects associated with season, management level, parity and climatic factors. Discussion will include general considerations in adaptation and heat tolerance, climatic characteristics of the specific test lactation and recommendations based on results of the study.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

12:00 NOON

April 21, 1978

Room 400

Kleberg Center

Beef Production in Nicaragua

by

Carlos Torres

The resources available for use for producing beef cattle in Nicaragua will be described including climatic conditions and terrain as well as discussion of comparative advantages of different regions. The Nicaraguan economy is based largely on agricultural exports including cotton, coffee, sugar and rice. Beef exports have increased in recent years. A study conducted by Carlos was directed at formulating recommendations to improve efficiency of beef production in Nicaragua. He will describe the procedures followed and his recommendations regarding management to improve efficiency.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR

12:00 NOON

February 24, 1978

Room 400

Kleberg Center

Simulation Of Beef Cattle Production Systems  
On The Western High Plains Of Venezuela

by

Jorge Ordonez

Jorge Ordonez has collected extensive data from herds on the Western High Plains of Venezuela and will use these as the basis for his dissertation. He will present his research proposal, including an illustrated description of the area and cattle, and progress to date. His objectives include:

1. Description of genetic and environmental parameters.
2. Validation of the TAMU Beef Cattle Production Systems Model for the area, management, etc.
3. Examine management and other alternatives for increasing production efficiency.

ANIMAL SCIENCE DEPARTMENT

ANIMAL BREEDING AND GENETICS SECTION

SEMINAR  
12:00 NOON

January 27, 1978

Room 400

Kleberg Center

APPLICATION OF THE TEXAS A&M UNIVERSITY BEEF CATTLE  
PRODUCTION SYSTEMS MODEL IN BOTSWANA

by

Dr. T. C. Cartwright

The Beef Production Systems Group has an agreement with the International Livestock Center for Africa (ILCA) to simulate intuitively chosen alternative production practices for Botswana in order to examine the effect on the various production components. The results of these simulations will be used to suggest the value of implementing certain practices as well as the order in which they should be implemented. This program will be described and discussed. The background of production resources in Botswana will be illustrated with slides; contributions will undoubtedly be made by Jim Sanders and Terry Nelsen, the other members of the group who have visited Botswana.

Appendix III

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XV. References

A General Cattle Production Systems Model.

I. Description of the Model

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Summary

A model for simulating beef cattle production under a wide range of management schemes and environments with cattle differing widely in genotypes for size, growth, and milk production is described. In the model, genotypes are specified as production potentials, which are reached only if past and present planes of nutrition are adequate. Intake of forage and/or other feed is simulated as a function of the size and physiological status of the animals and the availability, digestibility, and crude protein content of the feed. Animal performance is calculated from the nutrient intake and the animals' condition (fatness), degree of maturity, and genetic potential. The model has been used for simulating beef cattle production under several widely differing sets of environmental and management conditions in Guyana, Colombia, Venezuela, Botswana, Texas, and Midwestern United States and for simulating dairy-beef production systems in Colombia, Tanzania, and Botswana. Results of simulations of existing conditions have coincided rather closely with actual production levels.



## Introduction

In recent years, a primary objective of the Texas A&M University Animal Breeding Section has been to study differences in both biological and economic efficiency of beef production systems involving different cattle types, management schemes, and environments. Previously reported work (e.g., Long, 1972 and Long *et al.*, 1975) involved the use of a model developed to calculate herd outputs as well as the nutritional requirements and monetary costs associated with various cattle types with different specified levels of phenotypic performance under two different management schemes. Models of a similar nature were later developed at other institutions (e.g., Wilton *et al.*, 1974). The model reported in this paper differs greatly from these previously reported models.

Whereas, in the earlier herd production models, levels of cattle performance were specified as input data and requirements for these performance levels were simulated, the current Texas A&M Cattle Production Systems Model simulates levels of performance from specified feed resources and cattle production potentials. A primary consideration in the development of this model was that the equations used in simulating performance levels from specified feed resources and cattle production potentials should describe the biological processes involved. An attempt was made to make each equation biologically interpretable and not simply an equation that gave a "best fit" to some particular set or sets of data. This model can accommodate the simulation of production of cattle varying widely in genotype under any length of breeding season, any culling and selling policy, different supplementation

programs, and any set of environmental conditions, where the environmental conditions refer primarily to the feed resources. Feed resources are characterized on a monthly basis by crude protein content, by dry matter digestibility, and by per animal availability of dry matter. In simulating across years the feed resources can be specified either as static annual cycles or with different feed characteristics from one year to the next. Different simulated classes of animals can receive different planes of nutrition either by supplementation of by specifying different pasture characteristics for the various classes. Production of herds of cattle with different genotypes have been simulated by varying genotypic potentials for size and milk production; the model is constructed so that potentials for other characters such as maturing rate, lactational persistency, etc. can also be varied.

Nutritional requirements for herd sires and sales of culled sires are not considered in the model. With the exception of sires, production of the entire herd is simulated. Animal numbers, sizes (body weight and WM, a measure of body size that is independent of condition), and, if appropriate, reproductive status are updated monthly for each class of animals. All animals are classified by age, and breeding females are classified by month of lactation and month of pregnancy. The model is programmed in FORTRAN and is quite general with respect to major input-output relationships. That is, by making appropriate changes in the input parameters, the same model can be used to simulate production under widely differing sets of conditions.

### Description of the Model

The model consists of a main program and a number of functions and subroutines. The main program is used for input of information and for printing the output of the model, but it is primarily a herd dynamics program. The herd dynamics portion places almost no limits on herd size, proportions of animals in various classes, or management options such as selling policies, time or length of breeding seasons, or weaning policies. Such limits can be imposed by the user of the model by making the necessary changes in the subroutines and in inputs to the main program.

The GRO, FERT, and DIE subroutines are used in the simulation of animal performance. Characteristics of the feed resource available for the herd being simulated are specified in the GRO subroutine; in this subroutine, lean tissue growth rate, body weight gain or loss, and, if appropriate, milk production levels are calculated for each class of animals during each month of simulation. During a given month of simulation, animal size, degree of maturity, condition (fatness), physiological state, and genetic potential interact with forage quality and availability in the simulation of feed intake; this intake level interacts with animal size, degree of maturity, condition, physiological state, and genetic potential in the simulation of growth rate and milk production level. In lactating animals, milk production and growth compete for consumed nutrients. The performance of animals in one month of simulation affects these animals' size, degree of maturity, and condition at the beginning of the next month of simulation; hence, in the simulation of animal performance, animal characteristics inter-

act not only with current feed conditions but also the feed conditions of previous simulation periods.

Occurrence of estrus and, when appropriate, conception rates are simulated in the FERT subroutine for all classes of open breeding females during each month of simulation. Simulated fertility of heifers is a function of degree of maturity, condition, current rate of weight gain, and genetic reproduction potential; fertility of cows is simulated as a function of condition, rate of weight gain, lactational status, time since calving, and genetic reproduction potential. Since current rate of weight gain is simulated as a function of current plane of nutrition in the GRO subroutine, and since condition and degree of maturity are functions of past planes of nutrition, both present and past planes of nutrition interact with the genetic potentials of the animals being simulated in the simulation of fertility rates. In addition to the genetic reproduction potentials, the animals' genotypes for size and milk production have major influences on simulated fertility because the nutrient requirements for lean tissue growth and milk production affect the amount of fat that is gained or lost during a given month of simulation.

Death rates are simulated for each class of animals during each month of simulation in the DIE subroutine as functions of the time of the year and of the age, condition, and physiological state of the animals. Genetic production potentials and past planes of nutrition affect simulated condition and physiological status and, therefore, also affect simulated death rates. Milk production of the cows and its large effect on simulated growth of young calves have large effects on

the death rates of these calves. Dams of calves that die are transferred to a nonlactating class in the model; this transfer affects these cows' growth and fertility in subsequent months of simulation. A primary consideration in the development of the model was to allow all parts of the model to interact with each other in the simulation of any given production system.

#### Herd Dynamics

The herd dynamics section of the main program keeps records of the numbers of animals in the various classes and of the average weights and WM's of the animals in these classes. The size measure, WM, is discussed in more detail in a later section. For each class of open breeding females, the fraction of females that were in estrus during the previous month is also recorded. In the model there are various classes of cows and suckling calves and of weaned steers, sale heifers, and replacement heifers. Cows are classified by age in years and by month of lactation and month of pregnancy. Cows older than fifteen years of age are given the same age classification as fifteen year olds. Suckling calves are classified by age in months and dam's age in years. Weaned steer, replacement heifer, and sale heifer calves are classified separately by month of age. Yearling replacement heifers and yearling and two year old steers and sale heifers are classified by quarter-year (i.e., a period of three months) of age. For systems with older steers and sale heifers, three year old animals are classified separately from animals that are four years of age and older.

Depending on management policies, genotype, and plane of nutrition, cows can have their first calf at two years of age or at any

later age, in the model. Calves can be weaned at any month of age from two to ten months. During every month of simulation, the WEAN subroutine is called for each class of lactating cows; the fraction of the cows in the class whose calves are weaned at the end of the current month is returned to the main program. No provision has been made for weaning a different fraction of steers than heifers. The fraction of the calves weaned can be any function of the age, weight, and WM of the calves, the month of the year, and the age and pregnancy status of the dams.

At weaning, calves can be sold immediately or kept in the herd. Heifer calves that are kept in the herd after weaning can be placed in the sale heifer classes or the replacement heifer classes. Once heifers are in a sale heifer class they cannot be transferred into a replacement heifer class. Heifers can be transferred from a replacement heifer class to a sale heifer class of the same age at any month of age up to a year of age. However, heifers can be sold directly from the replacement heifer classes as well as from the sale heifer classes.

Each month the HRP subroutine is called, to calculate the fraction of heifers that remain in or are transferred into the replacement heifer classes, for the weaned replacement heifer calf classes and for heifer calves that are weaned and not sold at the end of the current month. The weight, WM, and age of the calves and the time of the year can be used in determining the fraction of the heifers to be kept as replacements. In addition, for calves being weaned during the current month, the age and pregnancy status of the dams can be used in

determining this fraction. A value, RC, is used in the calling argument of the HRP subroutine to indicate the total number of heifer calves that are needed as replacements. The value, RC, can be recalculated at any time based on current and/or desired numbers of animals in the various classes in the herd.

For all classes of animals, except females in the ninth month of pregnancy, the SP subroutine is called for returning to the main program the fraction of animals in the class to be sold at the end of the current month of simulation and the price per kilogram of these animals. Any function of the month of the year and the weight, WM, age, sex, pregnancy status and lactational status of the animals in the class can be used in determining the fraction to be sold. No provision has been made in the main program for selling lactating cows before their calves are weaned; however, for selling cow-calf pairs, the calves can be weaned and sold and the cows sold simultaneously.

In a particular month of simulation, steers are simulated first, followed by sale heifers, replacement heifer calves, cows and their calves, and yearling replacement heifers, respectively. In each case, the older classes are simulated before the younger classes in order to allow for the transfer of animals from a younger to an older class at the end of a month, after performance and sales during the current month have been simulated for both classes. This order of simulation is necessary, because in some cases animals from a younger class are added to an older class at the end of the month. Similarly, females in more advanced stages of pregnancy and lactation are simulated before those in less advanced stages. In the simulation of a given class, the

main program calls the GRO subroutine which calculates feed intake and growth rates for body weight and WM for this class and returns these values to the main program. For lactating cows, milk production level is also returned to the main program; this milk production level is used in the calling argument of the GRO subroutine for the milk consumption of calves belonging to this class of cows. In the simulation of any class of open breeding females that are at least nine months of age, the FERT subroutine is called to calculate the fraction in the class that are cycling and, during the breeding season, the fraction of the animals that conceive during the month. Obviously, the fraction predicted to become pregnant is used in the calculation of the number of animals that remain in the open class and the number that are transferred to the corresponding class in the second month of pregnancy, at the end of the month. For all classes, the DIE subroutine is called to calculate the fraction of animals in the class that are predicted to die during the current month.

#### An Overview of the Simulation of Animal Performance

The GRO, FERT, and DIE subroutines are used in the simulation of animal performance. As mentioned earlier, during a month of simulation, the GRO subroutine is called for each class of animals. Calling arguments for this subroutine include the weight, WM, age, lactational and pregnancy status, and sex of the animals in the class and the month of the year. The forage conditions being simulated are specified in this subroutine in the D, CP, and AVC vectors. These are each vectors of twelve values corresponding to the months of the year; the values in D and CP are the dry matter digestibilities and crude protein contents



of the forage, respectively, and the values in AVC are the weights of forage dry matter (expressed in kilograms) available per mature animal per day in the various months.

In the simulation of animal performance in the subroutine GRO, requirements for maintenance, pregnancy, milk production, lean tissue growth, and fat deposition are calculated for the animals in a group based on the animals' genotype, size (weight and WM), sex, condition, and pregnancy and lactational status. An intake limit is calculated based on animal size and age and on the digestibility, crude protein content, and availability of forage during the current month. The intake of suckling calves includes forage and milk. If intake equal to this limit is more than adequate to meet the animals' requirements, intake is simulated as the average of the limit and the amount needed to meet the requirement; all nutrients above the amount needed to meet these requirements are used for additional fat deposition.

If the intake limit does not allow a high enough nutrient intake to meet the above requirements of the animals in the class, the limit is used as the simulated intake, and milk production level and lean tissue growth rate are adjusted downward by amounts based on the fraction of the requirements that cannot be met by the intake. These adjustments are discussed by Sanders and Cartwright (1978). Maintenance and pregnancy requirements are not adjusted for the plane of nutrition in the model. Adjusted requirements are calculated based on the adjusted levels of growth and milk production; requirements for fat deposition are not included in these requirements. The requirements based on the adjusted levels of milk production and growth cannot

necessarily be met by the simulated intake levels.

If the simulated feed intake is greater than the feed requirement for the adjusted levels of performance, nutrients consumed in excess of the requirement are used for fat deposition. If the feed intake is not adequate to meet the requirements, fat deposits are mobilized to meet the requirements. If nutrients from the animals' intake and the complete mobilization of their fat deposits are inadequate to meet the adjusted requirements, lean tissue growth rate and milk production level are adjusted downward again. If such adjustments are necessary, the lean tissue growth rate is adjusted downward to a greater extent than simulated milk production.

For each class of open breeding females that are at least nine months of age, the FERT subroutine is called after the information from the GRO subroutine is returned to the main program. The calling argument for the FERT subroutine includes the month of the year and the weight, WM, age, daily weight gain, month of lactation, and the fraction that were in heat during the previous month of the females in the class. Breeding season for the production system being simulated is specified in this subroutine. Fertility is simulated as a function of the time since calving in cows, degree of maturity in heifers, and condition and rate of weight gain in both cows and heifers. The fraction cycling (i.e., in heat during the current month) and, if appropriate, the conception rate are calculated and returned to the main program.

The month of the year and the age, sex, weight, WM, and stage of pregnancy and lactation of the animals in the class are included in

the calling argument for the DIE subroutine, which is used to simulate the fraction of the animals in a class that die during the current month. The minimum death rate for all classes is set at the first of this subroutine. Death rates of calves born during the current month are simulated as functions of the month of the year and of the age of their dams, with higher death rates for calves out of very young and old cows.

For animals that are at least a month of age, simulated death rates are functions of the time of the year and condition of the animals, with higher death rates for thin animals. Death rates are adjusted upward for calves with larger adjustments for younger calves. For cows that calved during the current or previous month, death rates are also adjusted upward; for cows that calved during the current month, death rates are adjusted more for very young and very old cows to account for losses associated with calving difficulty and, especially for older cows, with failure to recover after parturition.

The size measure, WM, is used throughout the model in the simulation of animal performance. An animal's WM is assumed to be independent of condition and does not decrease in value even if the animal loses a large amount of weight. WMZ is WM at maturity and would be the animal's body weight at skeletal maturity if 25 percent of body weight were fat. WM corresponds to the animal's skeletal size and is what the animal would weigh if a specific percentage of his body weight were fat. This percentage of fat depends on the animal's degree of maturity for skeletal size. Unless plane of nutrition is decreased as animals get older, animals tend to get fatter as they get older. At birth, calves

are normally about three percent fat (Maynard and Loosli, 1965), but yearling steers with three percent body fat are extremely thin (Trowbridge *et al.*, 1918). It can therefore be reasoned that, if a size measure is to be independent of condition, the measure should allow a higher fat content at later ages and degrees of maturity. In the model all animals are assumed to contain three percent body fat at birth; mature animals whose weights are equal to their WM's are assumed to contain 25 percent fat. This value came from the earlier assumption (Sanders, 1974) that a WMZ of 480 kg would correspond to average size Hereford cows, and, assuming most of the weight loss is fat, cows of this size and condition that lose one-fourth of their weight are extremely thin and can be assumed to have depleted their mobilizable fat deposits. The fat content of animals whose weights are equal to their WM's is assumed to be linearly related to the degree of maturity for WM. In the fertility section of the model, which is a slight modification of the model described by Sanders (1974), WM is considered to be the minimum weight at which maximum fertility will occur in females of a given skeletal size and genotype. Genetic potentials for WM are used to specify genotype for size in the model.

The simulation of animal performance using the Texas A&M Cattle Production Systems Model is described in more detail by Sanders and Cartwright (1978).

### Application of the Model

The model has been used by the Animal Breeding Section at Texas A&M University to simulate production of beef cattle (Sanders, 1977; Cartwright, 1977; Davis et al., 1976; Ordoñez et al., 1977; and Nelsen et al., 1978) and dual purpose cattle (Cartwright et al., 1977 and International Livestock Center for Africa, 1978), and, in a revised form, by the United States Meat Animal Research Center (Notter, 1977) to simulate beef cattle production.

Sanders (1977) used the model to simulate production of cattle differing widely in genotype for size and milk production under two different sets of Central Texas conditions (environments). These two sets of conditions differed only in the availability of forage. The production systems simulated utilized native forage without supplementation for all classes of animals. Cows calved for the first time as three year olds. Two different breeding seasons were simulated for various genotypes under the two sets of forage conditions. Efficiency was defined as the ratio of total annual sale weight of cattle to total annual dry matter forage consumption, and was calculated for each genotype-environment-breeding season combination. Different genotypes for size and milk production were associated with maximum efficiency under the different environment-breeding season combinations. The efficiency values were assumed to represent net merit and were used in calculations of selection indices.

Cartwright (1977) reported results of simulations of Central Texas conditions involving different simulated genotypes for size and milk production under both spring and fall calving systems with calves sold either at weaning or after being finished on grain. Some genotypes

ranked differently for simulated efficiency under the different management systems.

Davis et al. (1976) used the model to evaluate alternative management strategies in two different regions of Guyana. For both regions, results of simulations of traditional management schemes coincided closely with actual production. After examination of various management changes considered feasible for the area, management schemes were suggested that, based on simulation results, would appear to increase production efficiency in the two different regions.

Ordonez et al. (1977) simulated different times and lengths of breeding seasons and different selling policies for beef production on the western high plains of Venezuela. His results from the model indicated that one of the breeding season alternatives that was simulated should be tested experimentally against the breeding seasons that are currently used in the region.

Nelsen et al. (1978) simulated production efficiency for cattle differing in genetic potentials for size and milk production under three management systems in Central Texas. Under one management system calves were sold at weaning; in the other systems calves were finished either on native forage or grain. All three systems involved spring calving. Although the efficiency rankings of the different genotypes changed little between systems, the differences in efficiency between genotypes were different for the different systems.

A modification of the model, which allows the simulation of production systems where cows are milked, was used in the simulations reported by Cartwright et al. (1977). Production of milk and beef was

simulated for three different sets of forage conditions assumed for a location in Colombia for cattle differing in genetic potentials for size and milk production. By placing relative prices on slaughter animals and milk, rankings for efficiency were evaluated for the various genotypes for size and milk production. This same modification of the model was used for simulating dual purpose production in Botswana (International Livestock Center for Africa, 1978).

Notter (1977) modified the model to allow the simulation of cross-breeding systems and compared the simulated performance of cattle with different genetic potentials in different breeding systems. Some changes in the equations for simulating animal performance were also made; personnel at Texas A&M University and at U.S. Meat Animal Research Center plan to cooperate in minimizing the differences between the models used by the two institutions with regard to the simulation of animal performance.

### Conclusion

The model was developed to allow the simulation of cattle production under a wide range of conditions. The herd dynamics section of the model allows the classification of animals into a large number of classes based on age and physiological status. The primary consideration in developing the equations representing animal performance was to accurately describe the biological processes. Although the basic structure of the model will remain about the same, the equations for simulating animal performance will be changed as more complete experimental information becomes available or as existing information is understood more completely.

Since the model has validated quite well with existing information regarding cattle production, use of the model in exploring the efficiency of different management schemes and genotypes within given sets of production resources has been considered to be justifiable. After simulating the efficiency associated with various management or genetic alternatives, the question "what should be done with the results?" must be answered. One answer is to present the results to producers; if this presentation takes the form of simply stating the efficiencies associated with various simulated alternatives, the producers involved are likely to gain very little. Livestock production is too dynamic, too irregular in its changes, and too different from one operation to another for a ranking of management alternatives or genotypes based on simulation results to give an adequate basis for decisions by producers. If, however, the simulation results cause an increase in knowledge concerning livestock production, this increased knowledge can obviously



lead to wiser decisions by producers. This increased knowledge is more likely to come from the coordination of existing information than from generating new knowledge.

If the simulation of production efficiency is to lead to a greater knowledge of livestock production, it is obviously necessary to understand why one system is predicted to be more efficient than another. For the model reported in this paper, it is fairly convenient to print a tremendously large amount of the intermediate information that is simulated for a given production system; for all previous simulations, a rather large amount of this type of information has been printed. The availability of this information coupled with an understanding of how the model works allows an in depth study of why one system is predicted to be more efficient than another. A study of this type can, of course, be quite time consuming. Although an occasional producer might have the time and inclination to become adequately familiar with a production systems model to benefit directly from the modelling, the biggest benefit producers are likely to receive from modelling is an indirect one. As the researcher-teacher uses modelling to increase his own understanding of production he can more effectively transmit useful knowledge to the livestock industry.

The Texas A&M Cattle Production Systems Model is planned to contribute to the total research and teaching program of the Texas A&M University Animal Breeding Section. Areas of inadequate knowledge have continuously been pointed out during the development and use of the model. Some research in these areas will be conducted by this section. As additional information related to cattle production

becomes available, the model will hopefully provide an adequate framework for coordinating the new information with other information.

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A General Cattle Production Systems Model.

II. Simulation of Animal Performance

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Summary

The methods used for simulating animal performance in the Texas A&M Cattle Production Systems Model are given and discussed. The GRO subroutine is used to calculate feed intake, changes in weight and skeletal size, and, if appropriate, milk production level. Growth rates from the GRO subroutine, size, condition, time since calving, and the fraction of the animals in the class that were in estrus the previous month are used in the FERT subroutine to simulate the occurrence of estrus and conception in open, breeding females. Death rates are simulated in the DIE subroutine as functions of the time of the year, the age and condition of animals in the class, and, for cows, whether or not they calved during the current or previous month. The information from these subroutines is used to update the numbers and characteristics of animals in the various classes at the end of each month of simulation.

Introduction

As discussed in the earlier paper of this series (Sanders and Cartwright, 1978), a primary consideration in the development of the Texas A&M Cattle Production Systems Model was that the equations representing animal performance should, as accurately as possible,

describe the biological processes involved. That is, each equation should be biologically interpretable. The equations representing animal performance are in the GRO, FERT, and DIE subroutines of the model. These equations give various measures of performance as functions of the feed and other environmental conditions and of the genotype of the cattle being simulated.

In the model described in this paper different environments or production resources are simulated primarily by varying forage quality and availability. Forage digestibility and crude protein content are specified on a monthly basis. The maximum amount of forage available per mature animal per day is also specified for each month of the year. In addition to the effects of weather on forage quality and availability, differences in weather conditions have been simulated by specifying different mortality rates for the various months of the year in different environments.

Genotypes are specified in the model as potentials for size, maturing rate, milk production, and reproductive performance. These potentials are fully met only if plane of nutrition is adequate; at lower planes of nutrition, performance levels are lower and are functions of the specified genetic potentials and of the simulated planes of nutrition.

Specification of Environmental Conditions  
and Genotypic Parameters in the Model

Characteristics of the feed resource available for the herd being simulated are specified in the GRO subroutine of the model. The feed resource is characterized on a monthly basis by the digestibility, crude protein content, and availability of the forage. In the GRO subroutine, D, CP, and AVC are each vectors of twelve values corresponding to the months of the year; the values in D and CP are the dry matter digestibilities and crude protein contents of the forage, and the values in AVC are the weights of forage dry matter available per mature animal per day in the various months. The digestibility and crude protein values in the D and CP vectors refer to the digestibilities and crude protein contents of the forage that is actually consumed by the animals and not of the total stand of forage. The value in AVC for a given month is the upper limit on daily forage dry matter intake of mature animals, expressed as kg per head, regardless of genotype for size. This limit on intake based on forage availability is used to reflect the fact, that for a given set of conditions, there is a limit on the amount of forage an animal can consume in a day, which may be less than the animal could consume if a larger quantity of forage of the same quality were available. In some cases this availability limit of mature animals would be a measure of the total amount of forage, of the quality specified in the D and CP vectors, that is available for grazing. In other cases this limit would be related to the amount of time that

can be spent walking and grazing during a day and the amount of forage that can be consumed per unit of time. This amount of time and the consumption per unit of time would be affected by forage density, distance of water and shade from available forage, and the amount of time during the day that exposure to the heat or cold limits an animal's forage consumption. This measure of the forage available to mature animals, the digestibility and crude protein of the forage, and the characteristics of the animals are used in the simulation of intake of animals of any age or degree of maturity. This simulation of intake and the simulation of animal performance from the simulated intake and the digestibility of the consumed forage are discussed in a later section of this paper.

In the DIE subroutine, death rates are simulated as functions of a minimum death rate for the animals, age of the animals, physiological state of the animals, and time of the year. The minimum death rate is assumed to be a measure of the environmental conditions being simulated. This minimum rate is adjusted upward by a multiplicative factor for the month being simulated, with larger adjustments for the months when cattle are under more stress in the environment being simulated. Except for baby calves, these multiplicative factors for the months of the year are the values in the CT vector. The CB vector in the DIE subroutine is a vector of twelve values for adjusting baby calf deaths for the month of the year. During a given month, stillbirths and neonatal calf deaths are simulated as the product of the value in CB associated with this month and a value from the CBA vector associated with the age of dam of the calf.



Values in CBA are higher for two and three year old cows and for cows that are eleven years of age or older than for cows that are from four to ten years of age.

Although the model has been made flexible enough to allow extreme differences in environments to be simulated, more flexibility would be desirable. It would be particularly desirable to more realistically include the effects of parasites and disease as aspects of the environment. Possibly the greatest limitation of the model is that the simulated environment does not interact with the management system. For example, no provision is made in the model for lighter or heavier grazing pressure to affect future forage production. Extensions of the model to remove at least some of these limitations are planned.

A primary reason for developing the model was to study differences in efficiency associated with different cattle types under different environmental and management conditions. There are important differences among cattle breeds and types for skeletal size, milk production potential, muscularity, fat deposition pattern, heat tolerance and temperament; cattle also differ for other characters, but much of the variability in at least most other characters can be accounted for by variability in the characters in the above list. In order to adequately evaluate the efficiency of the widely differing types of cattle that exist, it is important to be able to describe the genetic characteristics of cattle such that as much as possible of the variability among the various cattle types can be accounted for. The model has been developed with primary emphasis on being able to simu-

late production of cattle with different genetic potentials for mature skeletal size and milk production. Differences in maturing rate for skeletal size and differences in genetic reproduction potentials can also be accommodated by the model. Although with rather slight modifications, cattle with different degrees of adaptedness to a given environment, different degrees of muscularity, and/or different propensities for fattening could be simulated with the model, these capabilities have not been exercised.

The term WMZ is used to represent genetic potential for mature size in the model. WMZ is the body weight of an animal at skeletal maturity whose body weight is 25% fat. As discussed in the earlier paper of this series, WM is a measure of the animal's current skeletal size and is what the animal would weigh if a specific

percentage of his body weight were fat; this percentage depends on the animal's degree of maturity for skeletal size. At birth, WM is assumed to be the weight of calves that have three percent body fat. WMZ is WM at maturity and is the weight of mature animals that are 25 percent fat. For animals between birth and maturity, the fraction of WM that is assumed to be fat is linearly related to the animal's current degree of maturity for WM. WMA is used as the genetic input for mature size in the model and is WMZ of females.

The concept of WM was developed to allow a quantitative description of condition. Throughout the model the ratio of body weight to WM is used to measure condition. Brody (1945) concluded that weight at a constant condition could be estimated by a constant times the 4.3 power of wither height. Inspection of the data presented by Brody (1945, pp. 571-574) indicates that Holstein, Jersey, Guernsey, and Ayrshire females all reach approximately 86, 95, and 98 percent of their mature wither height at one, two, and three years of age, when on a moderate plane of nutrition. If WM is assumed to be proportional to the 4.3 power of wither height, animals on a moderate to high plane of nutrition should reach 52.3, 80.2, and 91.7 percent of their mature size for WM at one, two, and three years of age, respectively (e.g.,  $.523$  is equal to the 4.3 power of  $.86$ ).

Brody (1945) found that, for animals on a moderate plane of nutrition, growth rates of animals that have not yet reached puberty tend to be proportional to current size of the animals; for animals beyond puberty, he found growth rates to be proportional to the difference between mature size and current size. Of course, plotting

these two phases of growth results in the familiar sigmoidal growth curve. Since, in European breeds, well fed heifers and bulls usually reach puberty at about a year of age, the inflection point of the potential growth curve for WM was assumed to occur at twelve months of age in the model. The genetic potential for WM at twelve months of age is denoted by WMP. If WMP is set at 52.3 percent of WMA, using  $.0024 (WMA - WM)$  to represent the derivative of WM with respect to time gives an exact fit to the desired values of  $.802 WMA$  and  $.917 WMA$  as the WM values at two and three years of age. That is, using the integrated form

$$\begin{aligned} WM &= WMA - (WMA - WMP)e^{-.0024t} \\ &= WMA - (WMA - .523 WMA)e^{-.0024t} \end{aligned}$$

where  $t$  is age in days beyond a year of age, gives  $.802 WMA$  and  $.917 WMA$  as WM values at 730 and 1095 days of age.

In most breeds of cattle (especially European breeds), average birth weight is about one-fifteenth of mature cow weight. Therefore, in the model birth weight and WM at birth are both assumed to equal one-fifteenth of WMA. In the model, all months are assumed to have 30 days, so a year is assumed to have 360 days. If WM at birth is one-fifteenth of WMA and WM at a year of age is 52.3 percent of WMA, daily growth rate during a 360 day year would be  $.00127 WMA$ . If daily growth rate is calculated as  $.0024 (WMA - WMP)$  for females that are twelve months of age, the rate is  $.00114 WMA$ , if WMP equals  $.523 WMA$ . If the average growth rate in WM during the first year of life is greater than (or even equal to) the growth rate at a year of age (i.e., immediately following the inflection point of the

growth curve), the growth rates for the period immediately preceding and immediately following the inflection point would be quite different, if WM increased at an increasing rate during the first year of life. Therefore, growth in WM was assumed to be at a constant rate during the first year of life.

By setting WMP such that potential daily growth rate in WM, for the month after WMP is achieved, is equal to the potential daily growth rate during the first year of life, the potential growth rate for the periods immediately preceding and immediately following the inflection point of the potential growth curve are equal. In the model, size (both weight and WM) is updated on a monthly basis, and, after WMP has been achieved, potential growth in WM during a given month is simulated as  $30k(WMZ - WM)$ , where, for cattle of a given genotype and sex, k is a constant. At the end of n months beyond a year of age, potential WM can be calculated as

$$WM_n = WMA - (1-30k)^n (WMA - WMP).$$

For animals with WMZ equal to 480 kg, if k is equal to .0026, WMP is calculated as .518 WMA, and WM potentials at two and three years of age are calculated as .818 WMA and .931 WMA. Note the value of .0026 as compared to the earlier .0024 value; the change is due to the updating of size at monthly intervals, rather than instantaneously, in the model. This value, .0026, is used for k for animals with WMZ equal to 480 kg. For animals with a given mature size potential, k is calculated as  $.0026 (480/WMZ)$ . Using this equation for k gives a slower potential maturing pattern for animals with a larger mature size. Females with WMA's equal to 432 and 528 kg have

WMP's equal to 54.2 and 49.6 percent of their respective WMA values (remember that WMA is WMZ for females). At 24 months of age, potential WM values would be .846 and .791 times the respective WMA's.

Summarizing the equations for potential growth in WM, for animals with any mature size, WM at birth (BW) is simulated as one-fifteenth of WMA, WMP is simulated as

$$WMP = WMZ (BW + 360 (.0026) 480) \div (WMZ + 360 (.0026) 480),$$

daily growth rate in WM for animals with WM less than WMP is given by  $(WMP - BW) / 360$ , and daily growth rate in WM for animals with WM above WMP is given by  $k(WMZ - WM)$ ; k is calculated in the manner discussed above. These potential growth rates in WM may or may not be reached, depending on the plane of nutrition simulated from the specified feed characteristics. If a class of animals fails to achieve its potential growth rate, potential growth in later periods is based on the size that has been attained; that is, potential growth in WM is simulated the same as for a younger class of animals of the same sex and genotype that, because of a higher plane of nutrition, has attained the same WM as this older class.

Whereas postnatal growth rate is simulated as a function of genetic potential for growth and environment, prenatal growth is assumed to be a function only of genotype in the model. If the growth rate of the fetus is assumed to be proportional to the pregnancy requirement, the growth rate of the fetus during the nth month of pregnancy can be calculated as  $.00416 WMAe^{.522(n-1)}$ . Simulation of pregnancy requirements is discussed in a later section. Combining these three segments of growth (i.e., prenatal growth, growth from birth to a year of age, and growth beyond a year of age) gives a curve of poten-

tial growth that closely resembles a sigmoidal curve even though the segment from birth to a year of age is linear.

In addition to the variation in maturing rate associated with differences in mature size, genetic potential for maturing rate can be varied by changing the coefficient,  $k$ , used in the calculation of potential growth rate in WM for animals beyond a year of age.

The term PMA is used to represent genetic potential for milk production in the model. For seven and eight year old cows in the  $j$ th month of lactation, potential milk production is simulated as  $PMA \cdot e^{-.08j}$ . The potential milk production of these cows is simulated as .92, .85, .79, .73, .67, .62, and .57 times their PMA's for the first through seventh months of lactation, respectively. For cows that are less than seven or more than eight years of age, potential milk production is simulated as a fraction, CFA, of the potential for seven and eight year old cows. CFA is .98 for six and nine year old cows, .94 for five and ten year olds, .88 for four and eleven year olds, .8 for three and twelve year olds, .7 for two and thirteen year olds, and .58 and .44 for fourteen and fifteen year olds. Although all previous runs with the model have assumed the same shape for the potential lactation curve, genotypes with different lactational persistencies could be simulated by using different values in the exponent of the equation for milk production potential.

In the FERT subroutine of the model, fertility is simulated as a function of condition, current rate of weight gain, and genetic reproductive potential. For heifers, simulated fertility is also a function of degree of maturity for WM; for cows, simulated fertility is a func-

tion of lactational status and time since calving. For heifers, genetic differences in age at puberty can be simulated by changing the minimum degree of maturity for WM at which estrus occurs. For cows, different fertility rates can be simulated by varying the extent that lactation per se decreases the fraction of the cows that express estrus.



Relationships Among Genotypic Parameters and the Environment  
in the Simulation of Animal Performance

The subroutine GRO is called for each class of animals during each month of simulation. As discussed in the earlier paper of this series, a requirement based on potential level of performance is calculated for the animals in the class; this requirement is used in the simulation of forage intake and is the sum of the maintenance, pregnancy, lactation, and growth requirements plus, when applicable, a requirement for a gain in condition. These requirements are expressed as kilograms of digestible dry matter and the simplifying assumption is made that digestible dry matter is equivalent to TDN (i.e., the higher energy content of digestible fat is ignored).

The maintenance requirement is calculated as

$$M = .0306W^{.75} (WM/W)^{.5} (WMZ/WM)^{.15},$$

where W is body weight. For mature animals (i.e., WM equal to WMZ) with weight equal to their WM, maintenance requirement is calculated as  $.0306W^{.75}$ , which is equivalent to the formula given by N.R.C. (1963). It is also equivalent to the formula given by N.R.C. (1970), if the net availability of metabolizable energy is assumed to be .7, the metabolizability of digestible energy is assumed to be .82, and a megacalorie of digestible energy is assumed to be equivalent to .2268 kg of TDN.

The term  $(WM/W)^{.5}$  corrects the maintenance requirement for the condition of the animal. Klosterman et al. (1968) found higher maintenance requirements per unit of metabolic weight (i.e., body weight to the .75 power) for thin cows than for fat cows. Both Hereford and Charolais cows were used. Klosterman et al. gave an additive correction factor for maintenance requirements based on the weight to hip height ratio of the cows. Since weight-height ratios change considerably during the development of cattle, an equation based on weight-height ratio could not be expected to adequately describe the effects of condition on maintenance requirements of cattle differing widely in age. The multiplicative term  $(WM/W)^x$  was fitted to the results of Klosterman et al. based on assumptions regarding weight and height used in the development of the WM concept. The value of .508 was found for  $x$  and was rounded to .5 for use in the model. More details of the derivation of this exponent are given by Sanders (1977). Remember, for mature cows of a given skeletal size, if weight is equal to WM, body weight is assumed to contain 25 percent fat. WM is assumed to be a nondecreasing function; that is, WM does not decrease in value even if a large amount of weight is lost. By using the term  $.0306W^{.75}(WM/W)^{.5}$  to calculate maintenance requirements of mature cows, a ten percent change in weight is predicted to change maintenance requirements by about 2.5 percent. A ten percent loss in weight would be predicted to increase maintenance requirement per unit of metabolic weight by about five percent, but metabolic weight would be decreased by about 7.5 percent. Of course, if maintenance requirements were estimated as  $.0306W^{.75}$ , the ten percent change in weight would be predicted to

change maintenance requirements by about 7.5 percent.

The term  $(WMZ/WM)^{.15}$  corrects the maintenance requirement for the degree of maturity of the animal. As reviewed by the Agricultural Research Council (1965), young, immature animals have been found to have higher maintenance requirements per unit of metabolic weight than older, more mature animals. Using the figures given by A.R.C. for relating maintenance requirements to age and the potentials for WM predicted by the model for various ages, an exponent of about .25 in the multiplicative correction term  $(WMZ/WM)^X$  would appear to give approximately the correct amount of adjustment to maintenance requirements. However, using .25 as this exponent would likely overestimate the effects of immaturity on maintenance requirements for two reasons. First, young animals have an impetus to grow such that animals fed to maintain weight tend to make skeletal growth and lose body fat. Any inefficiency associated with this change of body composition could be reflected as an increased maintenance requirement of young animals. Changes in body composition and their requirements are considered directly in the model. Secondly, since animals tend to fatten as they mature, young animals tend to have less condition than more mature animals. Therefore, increased maintenance requirements per unit of metabolic weight in younger vs. older animals may be due partly to condition of the animals, which is considered directly in the calculation of maintenance requirements in the model. In an attempt to avoid correcting twice for these two factors, the exponent in the term  $(WMZ/WM)^X$  was set to the value of .15 rather than .25. Using .15 as the exponent gives maintenance requirements for one and six month old heifer calves

that are about 1.4 and 1.2 times as large per unit of metabolic weight as the requirements for mature animals (these values correspond to WMA equal to 480 kg).

For pregnant females, daily pregnancy requirement is simulated as

$$RP = .0000275WMA \cdot e^{.522(K-1)},$$

where K is month of pregnancy. This equation is a modification of the equation given by the Agricultural Research Council (1965), derived from the results of a serial slaughter study, and reported in an earlier publication. The equation given by the A.R.C. gave kcal of uterine contents as  $416.2 e^{.0174t}$ , where t is number of days from conception. Assuming pregnancy lasts 283 days, the A.R.C. equation would give 57.26 Mcal as the energy content of the uterus at calving. Since information in the model is updated on a monthly basis and since pregnancy is assumed to last nine months (i.e., 270 days), the formula  $be^{.0174(30K)}$  was set equal to 57.26 Mcal with K equal to nine, which gives .5218 as the value for b. Assuming that the efficiency of converting metabolizable energy to products of conception is .25 and that 3.6155 Mcal of metabolizable energy is equivalent to a kg of TDN, gives the cumulative TDN pregnancy requirement of  $.5773 e^{.522K}$ . By subtracting the cumulative requirement at the end of month K-1 from the cumulative requirement at the end of month K, the requirement for the Kth month can be calculated as  $.3957 e^{.522(K-1)}$ , which gives a daily requirement of  $.01319 e^{.522(K-1)}$ . If this requirement is assumed to correspond to a 480 kg mature cow weight (WMA), and if pregnancy requirements are assumed proportional to WMA, this daily requirement can be rewritten in the form given in the above equation for RP.

Potential milk yield is simulated as a function of genotype, age, stage of lactation, and condition. Genetic potentials for milk production for cows of different ages and stages of lactation were discussed in an earlier section of this paper. The ratio of body weight,  $W$ , to  $WM$  is used as a measure of condition in calculating potential levels of performance for both milk production and growth. If weight is at least as great as  $WM$ , condition is assumed to have no effect on these potentials. The potential levels of milk production for cows in lower degrees of conditions, expressed as fractions of the potential for cows of the same age, genotype, and stage of lactation whose weight is at least as great as their  $WM$ , are calculated as

$$CFX = 1 - ((WM - W) / (.33 WM))^3.32.$$

Cows whose weights are equal to .67 times their  $WM$ 's are predicted to give no milk, regardless of their genotype or stage of lactation.  $CFX$  is set equal to zero for cows whose weights are below .67 times their  $WM$ 's. Using this equation, condition is predicted to have little effect on milk production potential unless weight is less than 85 percent of  $WM$ . For cows weighing 95, 90, 85, 80, 75, and 70 percent of  $WM$ ,  $CFX$  is equal to .998, .981, .927, .810, .602, and .271, respectively. Combining this correction for condition with the genetic potential for milk production that was discussed earlier, milk production for cows of any genotype, of any age, in any stage of lactation, and in any degree of condition is calculated in the model as

$$PM = CFA \cdot CFX \cdot PMA \cdot e^{-.08J},$$

where  $J$  refers to month of lactation. The TDN requirement for lactation potential is simulated as  $.3PM$ , which assumes milk is 95 percent digestible and contains 16.1 percent

TDN, that metabolizable energy is converted to net energy in milk with an efficiency of .7, and that metabolizability of digestible energy is .82.

In addition to the actual requirements for lactation, maintenance requirements for lactating cows are calculated as 1.3 times the maintenance requirement that is calculated based on their size. This increase in maintenance requirement is based on results reported by Neville (1974), who fed both dry and lactating Hereford cows to maintain weight and found that the partial regression of feed intake on metabolic weight of lactating cows (feed intake was regressed on metabolic weight and fat corrected milk yield, without an intercept) was greater than the regression of feed intake on metabolic weight of dry cows (feed intake was regressed on metabolic weight without an intercept). As discussed by Sanders (1977), after allowing for the age of the cows in Neville's study and for a slight gain of weight by the cows, the regression of TDN intake on metabolic weight of dry cows was quite similar to the coefficient .0306 used in the model for calculating maintenance requirements. The partial regression of TDN intake on milk yield was also similar to the corresponding .3 value used in the model. The 1.3 value used for adjusting the maintenance requirement of lactating cows is the average of the value found by Neville and two values he cited from earlier studies.

As for milk production, lean tissue growth potential is simulated as less than the genetic potential in thin animals. If weight is less than WM, the potential gain in WM is calculated as the fraction  $c$  times the genetic potential for WM growth, where

$$c = 1 - ((WM - W) / (.25 WM))^{3.5}.$$

Animals whose weights are less than or equal to .75 times their WM's are predicted to make no lean tissue growth.

Since WM is assumed to be the weight of animals of a given fat content for a given degree of skeletal maturity and since this fat content is higher for higher degrees of maturity, the requirement for a unit of potential growth in WM depends on the stage of development of the animal. It is assumed that all weight gain contains at least three percent fat; that is, it is assumed that three percent body fat is essential to the animal, and that growth in lean tissue is accompanied by at least three percent fat (for low simulated planes of nutrition the animal can lose fat while making "lean tissue growth", but this simulated lean tissue growth contains three percent fat). For animals of a given genotype and degree of maturity for WM, the fat content of a potential gain in WM can be calculated as

$$Z = .03 + .22(2WM + GWM - BW)/(WMZ - BW),$$

where GWM is daily gain in WM. The equations for the requirements for the potential gains in WM include requirements for this level of fat content. However, if nutritional intake is not adequate for this level of fat deposition, growth in WM can occur with less fat being deposited.

In the model it is assumed that any animal, regardless of degree of maturity, whose weight is equal to his WM, has an eighteen percent body protein content. The difference between weight and WM is assumed to be fat, and the difference between weight and the body content of protein and fat is assumed to be water and ash. Therefore, the net energy requirement for gain would include the energy content of the fat

and protein that is deposited. If fat contains 9.1 Mcal per kg and protein contains 5.65 Mcal per kg, and the efficiency of converting metabolizable energy to net energy of gains in both protein and fat is .45, the TDN requirements per kg of fat and protein gain would be about 5.56 and 3.47 kg, respectively. The requirement for potential gain in WM is simulated as

$$Y = .8GWM + 5.56 (.22GWM)(2WM + GWM - BW) / (WMZ - BW),$$

where the first term accounts for eighteen percent protein and three percent fat in the "lean tissue" growth, and the second term accounts for the additional fat in the potential gain in WM.

In addition to requirements for maintenance, lactation, pregnancy, and growth in WM, if weight is less than WM, requirements for potential levels of performance include a requirement for gain in condition. The daily gain in weight associated with this gain in condition is one percent of the difference between WM and weight; this gain is assumed to be composed entirely of fat. The requirement for this gain in condition is simulated as  $5.56 (.01) (WM-W)$ .

The requirement for potential performance is calculated as the sum of the requirements for maintenance, pregnancy, lactation, growth, and gains in condition. After simulating requirements for potential levels of performance, forage (or other feed) intake is simulated as a function of forage digestibility, crude protein content, and availability and of animal size, degree of maturity, and potential levels of performance. For animals of a given genotype and degree of maturity for WM, three limits on intake are calculated; simulated intake is no greater than the minimum of these three limits. The three limits are a



physiological limit, a physical limit, and an availability limit.

The physiological limit sets the maximum TDN intake at 2.25 percent of WM. The physical limit is based on the passage of nondigested feed from the digestive tract and limits the daily intake of nondigestible dry matter to 1.07 percent of WM. This is the limit given by Conrad et al. (1964) to describe intake by dairy cows of forages with digestibilities below about .67. If intake is simulated as the minimum of the above two limits, simulated intake follows the two phase pattern as discussed by Montgomery and Baumgardt (1965) and Conrad (1966), where dry matter consumption is positively related to forage digestibility up to a point (using the above values, this point corresponds to a digestibility of .677), and is negatively related to forage digestibility when digestibility is higher. In some runs of the model the physical limit on intake has been set so that intake of nondigestible dry matter has been limited to one percent (rather than 1.07 percent) of WM.

If forage crude protein content is less than six percent, the physical limit on intake is adjusted downward. The limit is set as the fraction  $(CP/.06)^6$  times the limit based only on forage digestibility, where CP is the crude protein content of the forage. The physical limits on intake of forages with five, four, three, two, and one percent crude protein are calculated as 90, 78, 66, 52, and 34 percent of the limit for forages with the same digestibility and with crude protein content of at least six percent. This adjustment was derived from the results of Campling et al. (1962), who used straw with a crude protein content of 3.3 percent and different levels of

urea supplementation to give different levels of crude protein content. The straw was fed to dry, open cows, with each of four cows receiving each of the crude protein levels during different periods.

The availability limit is calculated for all animals except calves that have not been weaned. As discussed earlier, the AVC value for a particular month is the maximum daily forage dry matter intake by mature animals, regardless of genotype for size. The availability limit is calculated as AVC times the term  $(WM/WMZ)^{15}$ . Since the physiological limit and physical limit are linearly related to WM, simulated intake is positively related to size unless the availability limit is less than both the physiological and the physical limit. If, for mature animals of a given skeletal size (WMZ), the availability limit is less than the minimum of the physiological and the physical limit, additional increases in size will not result in increased simulated intakes. The term  $(WM/WMZ)^{15}$  gives a lower availability limit for animals at a lower degree of maturity, especially for very immature animals.

For animals that have been weaned, the intake limit, R, is calculated as the minimum of the physiological, physical, and availability limits. If the amount of energy supplied by this intake limit is less than the amount needed to meet the requirement for the animal's potential level of performance, R is used as the simulated intake, TN. If this requirement is less than the amount of energy supplied by the intake limit, dry matter intake is simulated as the average of the intake limit and the amount of dry matter necessary to meet the requirement for potential levels of performance. Intake in excess of

requirements is used for additional fat deposition. This consideration of requirements in the calculation of intake is necessary because animals with lower requirements tend to consume less forage even when forage digestibility is low enough that physical rather than physiological factors would be expected to limit intake in animals with higher requirements. For example, Elliott and Fokkema (1961) and Elliott et al. (1961) reported that lactating Africander and Mashona cows consumed considerably more forage than dry cows even when digestibility was less than .45.

For cows that are more than eight years of age, intake is adjusted downward by three percent for each year of age beyond eight years of age.

For calves that have not been weaned, the physical intake limit is calculated in the same manner as for other animals, but the physiological limit is corrected for the milk consumption of the calves such that the total TDN intake is limited to 2.25 percent of WM. As mentioned earlier, milk is assumed to contain sixteen percent TDN, but to account for the higher nutritional value of milk when consumed by the young nursing calf, the nutrient intake from milk is assumed to be twice the TDN content. This higher nutritional value is due partly to the rumen bypass of milk and partly to the other nutrients, besides energy, that milk supplies to the calf. Differences in simulated calf performance, associated with different levels of milk intake, would be underestimated if milk were not given an adjusted value for its nutrient content. Calves are assumed to consume all the milk produced by their dams, even if this amount of milk provides more TDN than the

physiological intake limit.

The forage intake limit for calves is simulated as the minimum of the physiological and the physical limit. As with other animals, if the requirement for the calf's potential level of performance is less than would be met by the calf's milk consumption and the forage intake limit, forage intake is set as the average of the amount that would be necessary to meet the requirement and the limit, where in each case the forage quantity has been corrected for the milk consumption. If the calculated forage intake of nursing calves is less than one percent of the WM value of these calves, intake is simulated as one percent of WM.

If simulated TDN intake is less than the requirement for potential levels of performance, growth in WM and, for lactating cows, milk production level are adjusted downward. Remember that "TDN" from milk is simulated as twice the TDN content of milk. CFI is the ratio of TDN intake to requirement for potential levels of performance; when this ratio is less than one it is used in the adjustment of gain in WM and of milk production. Gain in WM is adjusted to the fraction  $(.2 + .8CFI^{.6})$  of the unadjusted gain in WM. Similarly, milk production level is adjusted to the fraction  $(.1 + .9CFI^{.5})$  of the unadjusted milk production level.

Requirements for these adjusted levels of performance (if TDN intake was adequate to meet the requirements for the potential levels of performance, the levels are not adjusted) are calculated as the sum of the requirements for maintenance, lactation, pregnancy, and lean tissue growth. These requirements for adjusted performance levels are

calculated in the same manner as the requirements for potential levels of performance, except that requirements for lean tissue growth (with three percent fat) are calculated rather than requirements that account for the total amount of fat associated with the gain in WM.

The daily weight gain associated with lean tissue growth is denoted as DS and is simply the difference between the daily gain in WM and the gain in fat (exclusive of the three percent fat content of lean tissue growth) associated with this gain in WM. If this lean tissue growth, DS, is achieved, WM is increased by the gain in WM from which DS was calculated; that is, even if the fat associated with this gain in WM is not deposited, it is included in the gain in WM. Remember, WM is the weight of an animal of a given skeletal size if a specific fraction of his body weight is fat, where this fraction is positively related to his degree of maturity for skeletal size.

If CN, the TDN consumption, is adequate to meet REQ, the requirement for the adjusted levels of performance, daily weight gain is calculated as

$$DW = DS + (1/5.56) (CN - REQ) + .953 RP,$$

which is the sum of lean tissue growth, the gain in fat, and the gain associated with pregnancy, respectively. The gain in fat is the second term in this summation and is calculated as the amount of TDN, that is available after all other requirements are met, divided by 5.56, the assumed TDN requirement per unit of fat gain, which was discussed earlier. The last term in the above summation, which is the simulated weight gain associated with pregnancy, is calculated from the pregnancy

requirement that was discussed earlier, assuming that the gain associated with a nine month pregnancy is equal to one-eighth of the potential mature size of the cow (WMA). This entire gain associated with pregnancy is assumed to be lost at calving.

If simulated TDN intake is not adequate to meet the requirements for the adjusted levels of performance, fat is assumed to be mobilized to meet these requirements. If the animals in a class carry inadequate depot fat to meet the adjusted requirements, levels of growth and milk production are adjusted downward again, so that the nutrients from intake and from fat mobilization are adequate to meet the requirements. The total amount of fat available for mobilization per day is calculated as the total body fat, excluding the three percent fat included in the "lean tissue", divided by thirty. That is, it is assumed that all available depot fat could be mobilized during a thirty day period, if this amount of fat were necessary to meet the requirements for the adjusted levels of performance. Pregnancy requirements are assumed to be met, regardless of the plane of nutrition.

If nutrients available from intake and from the mobilization of fat are adequate to meet the requirements for maintenance, pregnancy, lactation, and lean tissue growth, daily weight gain is calculated as

$$DW = DS - (1/5.56) (REQ - CN) + .953 RP,$$

where 5.56 is assumed to be the amount of TDN replaced by the mobilization of a unit of fat. The same value, 5.56, is currently used in the model for both the amount of TDN needed to produce a unit of fat gain and the amount of TDN replaced by the breakdown of a unit of fat; however, different variable names are used in the model so that either or

both of these values could be changed if the necessity is indicated in the future.

If the adjusted levels of performance cannot be met from TDN consumption and the mobilization of body fat, the kilograms of TDN requirement that could be replaced per day from the mobilization of all depot fat during the month is calculated. If intake and this breakdown of body fat does not supply more nutrients than are needed to meet maintenance and pregnancy requirements, REQM, no simulated milk production or lean tissue growth occur, and all mobilizable fat is lost during the current month. For nonlactating animals whose maintenance and pregnancy requirements can be met by feed intake and fat breakdown, but whose lean tissue growth requirements cannot be completely met, all nutrients above the level needed to meet maintenance and pregnancy requirements are used for lean tissue growth; the simulated requirement for this growth is the same as the requirement for lean tissue growth that was discussed earlier. Body weight change is calculated as the difference between fat loss and the total of lean tissue gain and pregnancy weight gain.

For lactating cows, if less than 25 percent of the lactation requirement can be met after maintenance and pregnancy requirements are met, no simulated growth in WM occurs and all nutrients (from feed intake and fat breakdown) above maintenance and pregnancy requirements are used for simulated milk production. For cows that can meet their maintenance and pregnancy requirements and more than one-fourth of their lactation requirement from their forage intake and complete breakdown of their mobilizable fat, milk production and lean tissue growth

are simulated from the quantity of nutrients that are available and from an assumed priority for nutrients by the two physiological processes. The simulated priority for lean tissue growth and milk production can be represented schematically by two liquid containing tanks; the total volume of one tank would represent the lactation requirement and the volume of the other tank would represent the lean tissue growth requirement. The tops of the two tanks would be at the same level. One-fourth of the volume of the tank representing lactation requirement would be at a level below the bottom of the other tank. There would be an open connection between the two tanks at the level corresponding to the bottom of the tank representing growth requirements. The total volume of liquid in the system would represent the nutrients available after maintenance and pregnancy requirements have been met. The front and back side of each tank would be parallel and trapezoidal in shape with the top and bottom parallel. The tank representing lactation requirement would be wider at the bottom than at the top; the other tank would be wider at the top than at the bottom. Of course, if the volume of liquid in the two tank system were greater than one-fourth the lactation requirement, the height of the liquid in the two tanks would be the same. The calculated volume of liquid in each tank is the simulated quantity of nutrients used for the respective physiological process. The equations used in simulating this assumed priority of nutrient use are given by Sanders (1977). This priority system is used only when all depot fat is mobilized during the current month; hence, weight change is calculated for these animals in the same way as for nonlactating animals that deplete their fat deposits as the difference



between fat loss and the total of lean tissue and pregnancy weight gain. Of course, for males and open females there would be no pregnancy weight gain.

In summary, the GRO subroutine calculates feed intakes, growth rates, and milk production levels for the various classes of animals during each month of simulation. For each class of animals, both an intake limit, which is based on characteristics of both the forage and the class of animals being simulated, and a requirement for potential levels of performance are calculated. If this limit allows more than adequate intake to meet the requirement, intake is simulated as the average of the intake limit and the amount needed to meet the requirement. If the intake limit is not adequate to meet the requirement, lean tissue growth rate and, if appropriate, milk yield are adjusted downward. If requirements based on the adjusted growth and milk production levels cannot be met by the simulated nutrient intake, fat deposits are mobilized to meet these requirements. If nutrients from feed intake and the complete breakdown of fat deposits are inadequate to meet the adjusted requirements, lean tissue growth rate and, to a lesser extent, milk production levels are adjusted downward again.

Simulation of female fertility in the FERT subroutine was briefly discussed in the first paper of this series. The three basic fertility measures that are calculated in this subroutine are (1) PEST, which is the fraction of females that were not in heat during the previous thirty day period that come into heat during the current thirty day period, (2) CCYC, the fraction of open females that were in heat during the previous month that come back into heat during the

current month, and (3) PCON, the conception rate of females that come into heat. Four terms, CFW, CFDW, CFM, and CFT, are calculated in this subroutine and are used in the calculation of PEST, CCYC, and PCON.

The term CFW is used to correct the simulated occurrence of estrus and conception for the condition of the animals and is calculated from the ratio of weight to WM as  $((W / WM) - .75) / (1 - .75)$ . CFW is set equal to one if weight (W) is greater than WM and is set equal to .001 if weight is less than three-fourths of WM. Sanders (1974) gave the derivation of CFW from the results of Wiltbank et al. (1962). The size measure WM was first discussed by Sanders (1974) and was defined as the minimum weight for a given age (and genotype) at which maximum fertility can occur. As discussed earlier in this paper, WM, as calculated in the present version of the Texas A&M Cattle Production Systems Model, is a function of past plane of nutrition as well as of age and genotype.

Daily weight gain as compared to DWM, the minimum weight gain at which maximum fertility is assumed to occur, is used in the calculation of CFDW, which is a measure of current plane of nutrition. DWM is calculated as

$$DWM = GWM + .01 (WM - W).$$

GWM is daily gain in WM during the current month; DWM can be either less or greater than GWM, depending on the condition of the animals.

CFDW is calculated as

$$CFDW = 1 - 100 (DWM - DW)/WM,$$

where DW is daily weight gain; this equation was derived from the results of Wiltbank et al. (1962) and Wiltbank et al. (1964). CFDW is set equal to one if DW is greater than DWM.

CFM is a correction factor for degree of maturity in heifers and is calculated as

$$CFM = ((WM / (A8 \cdot WMA)) - A9) / (1-A9).$$

In most previous runs of the model, A8 and A9 have had the values of .6 and .67, respectively. In the calculation of PEST, CFM times .85 is the assumed fraction of heifers of the given degree of maturity, with CFW and CFDW both equal to one, that will reach puberty (i.e., come into heat for the first time) during the current month. Therefore, these above values for A8 and A9 imply that no heifers will come into heat before their WM is equal to forty percent of their WMA and that degree of maturity will no longer be a factor in determining fertility after WM is equal to sixty percent of WMA.

CFT corrects fertility rates for time since calving in cows and is calculated as

$$CFT = 1 - e^{-A5(30(j-1))^{3.9}},$$

where A5 is .0000009 and j is month of lactation ( in some recent runs of the model, j is months since calving; that is, dry cows as well as lactating cows are classified according to months since calving). CFT is intended to correct fertility for the time required for the reproductive tract to recover from the parturition process. CFT is set equal to one for heifers and for cows that calved four or more months prior to the current month.

The fraction of females in a class that come into heat during the current month that were not cycling previously is calculated as

$$PEST = .85 \cdot CFW \cdot CFDW \cdot CFM \cdot CFT.$$

The fraction, CCYC, of females in a class that were cycling previously and come back into heat is calculated as

$$CCYC = (CFW \cdot 1) (CFDW \cdot 1),$$

and the fraction of the class predicted to come into heat during the month is calculated as

$$ACC = CCYC \cdot ACC + PEST (1 - ACC),$$

where the ACC on the right hand side of this equation is the fraction of the animals in this class that were in heat the previous month.

PCON, which is the simulated conception rate of females that come into heat during the month is calculated as

$$PCON = .75 CFT \cdot 5 \cdot CFW \cdot 2 \cdot CFDW \cdot 2 \cdot MB(T),$$

where MB(T) is equal to one during the breeding season and equal to zero at other times. Of course the coefficient, .75, can be changed for simulating different production systems. The fraction, FC, of the animals in the class that conceive is calculated as the product of PCON and ACC; the fraction of the females that did not conceive that were in heat during the month is calculated as

$$ACC = (1 - PCON) ACC / (1 - FC).$$

The FC value and this recalculated ACC value are returned to the main program.

Specification of minimum death rates as environmental input parameters was discussed in an earlier section of this paper. Death rates are simulated as functions of these minimum death rates, of the animals' condition, and of the physiological state of the animals. For animals whose weight is less than their WM, death rate is corrected for condition; when weight is equal to 95, 85, and 75 percent of WM,

simulated death rate is 1.007, 1.307, and 4.234 times the death rate of animals of the same type with weight at least as great as their WM. Death rates are also adjusted upward by a multiplicative factor for calves that are less than a year of age; this adjustment is made regardless of their weight or condition and is a larger adjustment for younger calves. For calves in the first three months of life, an additional upward adjustment is made, if gains in WM have been less than the calves' genetic potentials; this is an additive adjustment and for calves whose WM's are 90, 70, and 50 percent of their genetic potentials for WM, the death rates are increased to .065, .204, and .358 above the previously simulated death rates, so that over 35 percent of the calves in a class would be expected to die during the current month of simulation if the average WM of the class were half of the calves' genetic potential for WM.

In brief summary, the GRO subroutine is called for every class of animals during each month of simulation to simulate growth rates in all cases and milk production levels for classes of lactating females. After information from the GRO subroutine is returned to the main program, the FERT subroutine is called for each class of open, breeding age females to simulate conception rates and the fraction of open females that are cycling. The DIE subroutine is called to calculate death rates for each of the classes. The information from these subroutines as well as information supplied by the subroutines dealing with management decisions is used to update the numbers and characteristics of animals in the various classes.

### Conclusion

The methods for simulating cattle performance that are presented in this paper were developed with the objective of, as accurately as possible, describing the biological processes involved. Although the model involves a considerable amount of detail, the authors of this paper realize that additional detail would be desirable in some parts of the model. The desirability of additional detail must, however, be balanced with the desirability of keeping the model as simple as possible. With a relatively simple model, those people working closely with the model can have a much better feeling of why the model responds in a particular way. In developing models of complex systems, many assumptions must be made because of nonexistent or insufficient information. Adding detail to the model would require that additional assumptions be made. This increase in the number of assumptions can greatly reduce the ability of those working with the model to understand the functioning of the model.

The model reported in this paper has provided a useful framework for studying various aspects of cattle production. As discussed earlier, the model simulates performance of cattle with a given genetic potential that have forage of a given quality available to them. This allows the flexibility to simulate an almost limitless variety of production systems. By coordinating the knowledge from different areas of Animal Science, the model allows a more thorough examination of production alternatives than would be possible without such a model. The model has been used to predict the most desirable sizes and milk production levels of cows for both beef cattle operations and dual

purpose operations (dairy and beef) under various environments and management conditions. The effects on production efficiency of the time and length of the breeding season, of different supplementation and improved pasture programs, of different ages at weaning, of different ages of selling, and of age at first breeding have also been simulated. Although the results of these simulations, as with any simulations of livestock production, should not be accepted as absolute truths (because of the assumptions that must be made in the development of a model), these results can be and have been very useful as a tool in formulating breeding and management plans. We are never likely to have perfect knowledge of all the factors that affect cattle production, but, nevertheless, decisions must be made. The use of the model, as an aid to decision making, provides the opportunity for wiser decision making than would otherwise be possible.

As should probably be expected, the number of questions answered by using the model has been small compared to the number of new questions asked during model development and use. Many of these questions would be difficult to ask without a model to use as a framework for coordinating information. The most obvious questions asked in the process of model development are related to the assumptions that are made; any assumption that must be made because of limited information implies a question regarding the accuracy of the assumption. These questions often have a question on the surface related to the accuracy of the values used in quantifying a particular relationship and a deeper question related to the form of the biological relationship. For example, in the model reported in this paper, assumptions were

made regarding the priority for nutrients of lean tissue growth and milk production. The question of the validity of these assumptions is an important one, but from this relatively simple appearing question other questions arise related to topics such as the priority of nutrients for various components of lean tissue (e.g., muscle and digestive tract), the priority of nutrients for pregnancy in the pregnant, potentially growing, lactating female, and the effects on the udder of undernutrition as this affects future nutrient priority between milk production and other biological processes.

Two other important questions that have arisen during model development and use have been related to fat deposition patterns and to changes in body composition during tissue mobilization. Variation in fat deposition pattern among different types and breeds of cattle is well recognized; however, the efficiencies of depositing fat in and mobilizing fat from different areas of the body are poorly understood. Although some studies have been conducted regarding the chemical makeup of weight losses associated with low planes of nutrition, the effects of genotype, condition, and severity of the underfeeding on this makeup have not been adequately studied.

Because of the almost limitless number of types of production systems and because of the dynamic nature of cattle production as a part of the agriculture and economy of a nation and of the world, a convenient framework for studying cattle production is highly desirable. The Texas A&M Cattle Production Systems Model allows alternative production strategies to be studied in a short period of time. Many such strategies could not be studied with live animal experimentation



because of space and facility limitations. Even if these limitations did not exist, a long period of time is required for production system experimentation with live animals; by the time the experimentation has been completed, economic or environmental conditions, which originally may have caused the experimentation to be appropriate, may have changed considerably.

The great mass of literature published in recent years in various fields of Animal Science has made it quite difficult for people in a particular field of Animal Science to keep up with advancements in other fields of Animal Science. In the synthesis of information from various fields of Animal Science into a production systems model, those involved in model development obviously face the opportunity of keeping up, to a greater extent than would otherwise be the case, with advancements in the various fields. However, more importantly, a model that forms a framework for studying cattle production can provide the possibility of observing how developments in a particular field fit in with present knowledge in the various fields of Animal Science. By viewing advancements in a particular field as part of a coordinated body of knowledge, new knowledge can be comprehended and utilized more effectively. Although extensions are needed and planned, the model reported in this paper has proven effective in this coordination of knowledge from the various fields of Animal Science.

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