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Livestock Tick Research Program

at

International Center for Insect Physiology and Ecology

Nairobi, Kenya

Project No. 931-1038

RAC Team Review

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OBJECTIVE OF THE RESEARCH

To investigate the ecology and physiology of cattle ticks with the aim of developing environmentally and economically sound controls for ticks and tick-borne diseases.

RAC ACTION OCTOBER 31, 1978-NOVEMBER 1, 1978

The Research Advisory Committee (RAC) to AID recommended that an in-depth team review be conducted at ICIPE by RAC in about one year after the project was initiated (RAC Minutes-10/31/78-11/1/78). Additional funding or continuation of the project is subject to a favorable report from the team.

The team will evaluate the project in depth and make recommendations to RAC in order to (1) evaluate the accomplishments of the first year; (2) evaluate the work plan and budget for Fiscal Year 1980; and (3) determine if the project should be terminated at the end of two years or continued and funded for a third year.

RAC REVIEW TEAM RECOMMENDATIONS

The Review documented that significant progress has been made on the ecology and physiology of cattle ticks and that funding is recommended by the RAC Team for the third year. The work and budget plan for Fiscal Year 1980 as outlined in Attachment #1 appears sound and should lead to further research accomplishments during 1980.

REVIEW OF CATTLE TICK RESEARCH PROJECT

I. Economic and Social Impact of Cattle Ticks and Tick-Borne Diseases

Cattle ticks and tick-borne diseases are a major limiting factor in cattle production in the East African region. While accurate livestock data are not readily available in Kenya, that country does provide us with some insights into the serious economic impacts of tick-related diseases. Kenya's cattle population is estimated to total 10 million head, of which

1 million are regarded as superior quality animals. At the very least 3% of the national herd is lost each year to tick-borne diseases and approximately 50,000 of the superior quality animals die because of these diseases.

Ticks clearly are a major constraint in the development of many national agricultural sectors in general and their livestock sub-sectors in particular. Milk and meat yields are reduced as a result of the morbidity and mortality associated with tick-borne diseases like East Coast Fever. The earning potentials of livestock producers, both large and small, are reduced as a result and consumers are denied the benefits that would accrue to them from the development of a healthy livestock sub-sector, i.e., relatively inexpensive meat and milk. On the macro level national income suffers as tick related morbidity and mortality prevent countries suffering infestation from earning foreign exchange through the export of beef and dairy products. In addition to preventing the full development of indigenous livestock population, ticks also exclude the possibility of importing the exotic breeds which have the potential for increasing production, but lack the needed immunities to survive in tick infested areas. The movement of cattle into new grazing areas is often prevented by tick infestations. This may result in overgrazing and environmental problems.

In addition to their economic importance, livestock are not often assigned important cultural attributes that are not common in Western countries. In some areas of Africa an individual's social standing is directly related to the size of his cattle holding. In other areas cattle are used as a means of exchange in tribal barter transcations or employed to satisfy social obligations like dowries or wife payments.

The prime control for ticks is the use of chemical pesticides (acaricides) as dips. These chemical controls, however, have the following problems associated with them: (1) high levels of tick resistance to the pesticides; (2) pesticide toxicity in the livestock; (3) environmental pollution; (4) high cost of pesticides; (5) immobilization of the cattle for frequent dipping; and (6) rendering cattle herds more susceptible to tick attack when dipping ceases for some reason. Unfortunately cattle which have been protected from ticks are more highly susceptible to tick attack and death than previously tick-exposed cattle. Thus when the dipping schedule is interrupted because of pesticide or manpower shortages, these animals are especially vulnerable. When this happens, cattle loss is increased and represents a substantial loss to the farmers and the region.

Although the economic losses to ticks and East Coast Fever transmitted by ticks are indeed high, the social effects of cattle losses are important factors. Indeed, cattle represent personal wealth and prosperity and as such are essential to the marriage and family system in Kenya.

II. Research Progress on Ecology and Control of Cattle Ticks

A. Cattle Tick Population Fluctuations. Known numbers of the cattle tick *Rhipicephalus appendiculatus* were introduced into experimental paddocks of various sizes (Attachment #1). Individual European cattle (*Bos taurus*) were then pastured in these paddocks. Tick population fluctuations in the paddocks and on the cattle were observed to be the greatest in the smallest area paddocks and the least fluctuations occurred in the largest paddocks.

B. Persistence of Ticks in Infested Pastures. During the first year after known numbers of ticks were introduced into paddocks, the tick populations increased about 100-fold in number (Attachment #1). Thereafter, a gradual decline in number of ticks occurred over the next 2 years until tick populations on both cattle and pasture became greatly reduced. This reduction in tick populations was proposed to be due to the development of some form of resistance in the exposed cattle.

C. Tick Survival on Cattle Previously Exposed to Ticks. Preliminary data suggested that exposing cattle to about 500 female ticks stimulated a physiological reaction in the cattle that reduced tick survival on these animals (Attachment #1). When known numbers of larval, nymphal, and adult ticks were placed on previously tick-exposed cattle, reduced numbers of ticks were able to feed to repletion on the exposed cattle. The results suggest a type of "acquired resistance" to tick attack develops in cattle after heavy tick-feeding exposure (e.g., resistance to *Boophilus* ticks in Australia). Subsequent experiments were run to explore the effects of previously tick-exposed cattle on survival of introduced tick populations. Tick populations associated with the previously tick-exposed cattle are feeding and developing poorly, whereas tick populations in paddocks with previously unexposed cattle are feeding and developing normally. These

tick populations in the paddock and on the cattle are being continuously monitored.

D. Survival of Ticks in Pastures without Cattle. When cattle were removed from tick-infested paddocks, survival of ticks in these paddocks was observed (Attachment #1). The results showed that without the cattle host, larval ticks survived for 12-15 months; nymphal ticks for about 18 months; and adult ticks for about 2 years. Survival of all stages of ticks is also being investigated in one meter diameter areas. Included in this study is the monitoring of temperature, soil moisture, and relative humidity and the measure of tick activity.

E. Field Studies of Natural Tick Populations. In cooperation with the Veterinary Research Department of the Kenya Agricultural Research Institute, field studies are being made of natural tick populations. The objective is to measure the possible impact of previously exposed cattle to ticks on tick populations.

F. Laboratory Studies of Tick Feeding. All instars of ticks fed on previously tick-exposed cattle were observed to be reduced in size and the females produced fewer eggs compared with ticks fed on tick naive cattle. An experiment is underway to investigate the effect of sequential feeding of larval, nymphal, and adult ticks on tick-exposed cattle under controlled conditions.

G. Ecology of Cattle Ticks from Different Environmental Regions of Kenya.

In cooperation with scientists of the Veterinary Research Department of Kenya. ticks (*R. appendiculatus*) have been collected from three locations in Kenya: Mbita Point (ICIPE Field Station), Lake Victoria; Ukunda on the coast near Mombassa; and at Mugaga. The ecology of these tick strains will be investigated for their relative survival and development under various temperature and moisture conditions. Studies will also be made on the

ability of these tick strains to transmit various races of the East Coast Fever disease organism of cattle (Theileria parva).

H. Effects of Molasses Grass on Ticks. Previous studies reported that molasses grass (Melinus minutiflora) reduced the presence of ticks on the grass. Chemical extracts from this grass were not found to be repellent to ticks. Some preliminary data suggest that the hairiness and syrupy secretion on the hairs of the grass may itself hinder the ticks using this grass as a "staging point" to attach to cattle.

III. Research Progress on Physiological Studies of Ticks

Current research on tick physiology by the ICIPE Tick Physiology Unit has focused on efforts to: (1) evaluate the possible use of certain insect hormones and antihormones as agents for tick control; (2) identify tick endocrine secretions and elucidate the roles of these hormones in growth, development, and reproduction; (3) study tick pheromones and their effects on clustering and mating behavior. Both the quality and quantity of the research effort by this group is creditable. Before commenting on the significance of their results and the future promise of these lines of investigation, the major results will be summarized.

To determine if they influence mortality rates, the molting pattern, and egg production of Ornithodoros porcinus porcinus, beta ecdysone and ponasterone, a phytoecdysterone, were administered topically or via artificial blood meals to both nymphs and adults. Topical applications of the ecdysteroids (at dosage rates of 1-5 μg/tick) caused mortality at rates always below 80% among both nymphs and adults and caused supermolts to occur among a relatively small percentage of the surviving adults. When either ecdysteroid (at dosage rates of 1-8 μg/ml blood) was placed in blood meals of ticks, considerable mortality occurred among both nymphs and adults, and in ponasterone treatments ranged up to 90% among both males and females.

The percentage of adults undergoing supermolts was also high with 74% of beta ecdysone fed females exhibiting at least one additional molt. The supermolted females were larger than normal individuals, but were less efficient in the conversion of their blood meals into eggs. In nymphal O.p. porcinus the average molting time of survivors was decreased.

Precocene, a chemical that in insects has an anti-juvenile hormone effect, was tested against female O. p. porcinus. At the dosage rate applied the precocene treatments caused some increase in mortality (up to 20%) and caused a delay in oviposition. Pretreatment of females with either beta-ecdysone or juvenile hormone III antagonized the effects of the precocene. However, it was concluded that precocene is not a specific inhibitor of juvenile hormone in the females, but the mechanism of action appears to involve a general toxicity of the compound. In addition to tests on females, nymphs exposed to precocene experienced delays in molting that could be reversed by treatment with beta ecdysone.

As part of efforts to elucidate the involvement of specific hormones in the regulation of tick development and reproduction, several studies involving endogenous ecdysteroids are in progress. In addition to contributing to a basic understanding of tick physiology, this line of investigation is also significant because preliminary finds suggest that the cycle of ecdysteroid production in Rhipicephalus appendiculatus influences the Theileria parva developmental cycle in the tick. This knowledge may have application in attempts to control T. parva. The present research approach involves culturing tissues from different organs of the tick and a monitoring of levels of ecdysteroid production. In related cooperative research with scientists from the ICIPE Chemistry/Biochemistry Unit, the chemists have perfected radio-immunoassays (RIA) that, significantly, have enabled identification of alpha and beta ecdysones in homogenates of R. appendiculatus egg extracts.

Evidence from RIA is reinforced by results employing chemical identification techniques. Efforts of the Physiology Unit have also contributed to the growing body of knowledge of the influence of pheromones on tick behavior.

When off the host a pheromone is known to stimulate the assembly or clustering of O. p. porcinus and many other argasid ticks. A significant finding relative to this assembly pheromone has resulted from collaborative research with the Chemistry/Biochemistry Unit. Guanine, from O.p. porcinus excrement, was shown to stimulate clustering and chemically purified guanine from commercial sources elicited similar responses. Additionally, an unidentified second component of tick excreta exhibits some assembly pheromone activity. Another study of pheromones has dealt with the species specificity of the "on-the-host" aggregation-attachment responses of several Amblyomma species. Results provided information about the attachment and aggregating responses of these ticks, and, with the particular bioassay employed, shows that little species specificity exists between A. variegatum and A. gemma. In contrast, Amblyomma eburneum and A. cohaerens females would attach only in the presence of conspecific males.

The employment of insect growth regulators (IGR) and pheromones in the control of pest insects offers appreciable promise, (e.g., the control of red-banded leaf-rollers on apples). The directing of similar methods against ticks has only recently been considered. There is virtually no knowledge of the tick endocrine system on which to base plans for utilizing IGR's such as ecdysteroids or precocene. Also, efforts to understand the influence of pheromones on tick behavior or to isolate and characterize them chemically are in early stages of investigation. Of course any information that enhances our knowledge of these subjects helps evaluate their potential for use in integrated control approaches. Considered in this framework, most of the findings of the ICIPE Tick Physiology Unit are

significant.

When considered in terms of potential for control application in the near future, the experimental results of this unit are not encouraging. The tests of the ecdysteroids against O. p. porcinus do not suggest that these chemicals have a great ability to disrupt development and reproduction. They may have greater possibilities in the control of East Coast Fever tick (Rhipicephalus appendiculatus). Precocene, as it was tested against O. p. porcinus also showed little promise as a control agent. Neither do any of the results from the pheromone investigations indicate definite avenues for applicati

IV. Research Progress on Immunological Studies

A. Introduction. The immunological approaches carried out in this program are not part of the physiology and ecology of ticks project (SCI-1038) as funded by AID/DSB/AGR/1 in Fiscal Year 1979 and Fiscal Year 1980.

However, the ICIPE staff believes so strongly, based on research in Australia and observations in Africa, that the immunological approaches are an integral and inseparable part of the total program along with ecological and physiological approaches for tick control that limited funding has been obtained for immunological studies that complement the AID/DSB supported studies.

Results to date seem to substantiate the position of the ICIPE staff on this. After only one year of work, output from this project has been impressive. The ICIPE staff will submit for AID/DSB consideration a proposal for DSB participation in the immunological studies.

B. Basis for Immunological Approaches. Scientists have reported the phenomenon that, following exposure to tick infestation, resistance to further tick infestation is acquired in the cattle which reduces the ability of ticks to feed on such animals. Australia has incorporated this phenomenon into its national policy to control the tick, Boophilus microplus

In addition, through a second phenomenon, it has been shown that mammalian antibodies ingested in the blood meal of ticks pass unchanged through the gut wall of the tick into its haemo-lymph. Therefore, if antibodies produced in mammalian hosts against tick antigens are ingested by feeding ticks, it is possible that an antigen/antibody reaction may occur in the ticks resulting in an adverse effect on the ticks. Such antigens may include broad-spectrum endocrine regulators of the tick vectors. Within the physiological approach of this project are included studies to identify such endocrine regulators.

In summary, it appears logical that the two phenomena described above can be combined in that animals can be made resistant to tick infestation and immunized against target antigens for ticks.

C. Evaluation of the Accomplishments of the First Year (Fiscal Year 1979)

(1) An experimental skin test to identify and measure host cattle resistance against tick infestation has been developed. Additional evaluation and refinement of the test is ongoing. This skin test procedure would be valuable as a screening of groups of animals to identify the ones possessing protective active immunity and those not protected.

(2) ICIPE initiated controlled studies to show that host animals develop resistance following prolonged exposures to tick (*R. appendiculatus*) infestations.

D. Evaluation of Work Plan for Second Year (Fiscal Year 1980)

(1) The studies begun in C above will continue and if satisfactory results occur and results indicate that reliable methods are developed to show that host resistance from tick infestation can be artificially induced the subject will be studied in further detail, i.e. the dynamics of the process will be investigated from the standpoint of the level of protection as a function of time from exposure.

(2) Investigation of the possibility that mammalian anti-bodies are transferred unchanged from the blood-meal of the tick directly into the haemolymph.

(3) Investigation of the antigenecity of materials obtained from the development stages of the tick.

E. Comment

Bitter experience in Africa has shown that efficient dipping of cattle with acaricides at prescribed frequency results in a population of cattle fully susceptible to tick-borne diseases. If for any reason acaricide control fails, tick populations increase in number over time and catastrophic losses of cattle occur from tick-borne diseases and tick debilitation. The breeding capacity of the tick R. appendiculatus is phenomenal--over 4000 progeny from one female. Therefore, any future tick-borne disease control program must include multi-pronged attack, including effective chemotherapeutic drugs to protect and treat young animals plus the use of immunological techniques to protect semi-mature and mature cattle along with programs of cattle dipping in acaracides.

F. Summary

The work now ongoing at ICIPE is based upon sound and accurate scientific observations combined with empirical field experience. The studies being carried out are well designed and are being carried out by highly competent personnel at ICIPE with close collaboration with the Kenya Agriculture Research Institute and International Laboratory for Research on Animal Diseases (ILRAD). (See sections on personnel qualifications and collaboration with other institutions).

AID/DSB/AGR/L should give consideration to a new proposal from ICIPE to expand the immunological studies now ongoing and demonstrated to be promising as a component in a total research effort for developing a program for herd control of tick-transmitted diseases.

V. Training at ICIPE Research Center

The International Center for Insect Physiology and Ecology (ICIPE) has a scientific staff of excellence and is playing an important and growing role in training in the ecology and physiology of insect vectors of disease and insect crop pests. As the Center evolved, its aim was to tailor entomologists for specific tasks that are related to economic and social development.

Functionally, ICIPE has been in existence since 1972. The training output as indicated in Attachment #2 has grown rapidly. The ICIPE training scheme has operated extremely successfully, offering young postdoctoral scientists, from institutions in developing nations, opportunities to conduct research at the ICIPE during their sabbatical leave or before entering universities. It represents a unique experiment within Africa where scientists opt to work in a research center in a developing country.

From 1974, ICIPE started implementing training, using as its resource the research scientists in its programs. Thus, from a modest beginning of an output of 3 manyears in 1972, this climbed steeply to 16 manyears in 1974. In 1974 it was possible to initiate graduate research training for manpower development. During this period other institutions recognized ICIPE's competence and numerous requests were made for training in specialized areas of research in insect ecology and physiology. A scheme was also initiated for scientific motivational training of high school graduates whose aim was to pursue science-based careers at universities.

In 1977 a fully-fledged training division was set up within ICIPE with two training officers to coordinate the activities. During that year the ICIPE started a group training course in environmentally sound pest and vector management for young scientists from developing countries. Through 1979

there have been 74 participants from Africa, Asia, South America and the Middle East who have completed this course.

Technical training at the ICIPE has received a high priority starting from the formation of the Center. It is hoped that research training and technical training will be parallel to provide the invaluable back-stopping services with the technical know-how.

The Center places great importance on research communications which provide a forum for exchange of research findings among scientists, in developed and developing countries. This is done in form of seminars, conferences, and international study workshops. Since 1972, the Center has hosted eight workshops ranging from pest and vector research to science and technology information transfer.

So far, the bulk of funding for the ICIPE training has been through the Center's core budget. However, funding for specific training programs has come through Ford Foundation, UNEP, ADAB (Australia), SAREC, UNIDO, UNESCO, CFTC, Commonwealth Foundation, and ORSTOM.

As the ICIPE begins to achieve its projected goals in research, training will definitely have to grow. Thus it is being properly planned so that training benefits not only from the research outcome, but also from the research process.

VI. Research Competence

ICIPE is a relatively new (1972) research institution conceived by its present director and a group of international eminent scientists to carry out research on insect vectors of diseases and insect crop pests. The institution is located on the campus of the University of Nairobi with fully fledged field stations in three contrasting ecological regions of Kenya.

ICIPE has four technical support services: the insect and animal-

breeding service; the field stations management service; the outreach management service; and the workshops and laboratory management service. These services provide scientific technical and mechanical back-up to the research programs and research unit.

ICIPE has a highly qualified, well-motivated, competent resident staff of research scientists, the core of which presently come from the developed world. These expatriates are highly qualified and well recognized scientific authorities in a wide variety of scientific disciplines. The Center also engages a number of young, enthusiastic and capable scientists of African origin who are progressing toward replacing the expatriate scientists. The scientific staff, both expatriate and local origin, carrying out the AID financed project of research on the ecology and physiology of ticks can only be described as outstanding in both academic credentials and research experience coupled with impressive scientific motivation.

VII. Cooperation Among Scientific Institutions

The RAC Review Team was impressed with the genuine cooperation and interaction among the ICIPE scientists involved in the cattle tick research and both the International Laboratory for Research on Animal Diseases and the Veterinary Research Department of the Kenya Agricultural Research Institution. These groups of scientists are actively sharing equipment, facilities, and knowledge. None of the RAC Team has ever observed such active cooperation and interaction among different scientific groups before. Indeed, this was an encouraging aspect of this research project.

VIII. BUDGET AND SCIENTIFIC PERSONNEL INVOLVED IN TICK RESEARCH

The funds granted for this project have been effectively spent to accomplish the objectives of the research. The details of the spending for FY 1979 and proposed budget for FY 1980 are detailed on page 16.

The total number of scientists at ICIPE involved in cattle tick research and control is 9. The number and their percentage effort are shown on page 17. Only a small portion of the scientific staff are supported by AID funds.

Project Budget and Funding Sources

1978-1980

First Year Actual Expenditures

Sept. 29, 1978 Through Sept. 28, 1979

(U.S. $)

COMPONENT

ITEM	PHYSIOLOGY	ECOLOGY	TOTAL
Personnel	14,008	80,963	94,971
Travel	304	1,756	2,060
Consultants	---	---	---
Materials	1,558	9,003	10,561
Equipment	581	3,361	3,942
Israeli Services	8,000	8,000	16,000
Total	24,451	103,083	127,534
SOURCES			
AID	18,000	104,000	122,000
Others	6,451	(917)	5,534
Total	24,451	103,083	127,534

Second Year Projected Expenditures

Sept. 29, 1979 Through Sept. 28, 1980

(U.S. $)

COMPONENT

ITEM	PHYSIOLOGY	ECOLOGY	TOTAL
Personnel	16,900	97,677	114,577
Travel	4,000	6,000	10,000
Consultants	---	1,000	1,000
Materials	14,000	17,800	31,800
Equipment	1,000	3,500	4,500
Israeli Services	8,000	8,000	16,000
Total	43,900	133,977	177,877
SOURCES			
AID	18,000	104,000	122,000
Others	25,900	29,977	55,877
Total	43,900	133,977	177,877

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Analysis of Time Spent on Tick Research

	Scientist's Name	Immunology	Ecology	Physiology
ICIPE	1. Dr. M.P. Cunningham	40%	40%	20%
	2. Dr. R. Newson	+	100%	+
	3. Mr. D. Punyua	+	100%	+
	4. Mr. J. Chiera	+	100%	-
	5. Mr. A. Mongi	100%	+	-
	6. Miss M. Binta	100%	+	-
	7. Dr. F. Obenchain	+	+	100%
	8. Dr. Ellis	+	-	100%
	9. Mrs. C. Mango	+	-	100%
	No Cost - Other Funding			
	Support Units			
	10. Bioassay (2 technicians)			40%
	11. Dr. S. Waladde (Sensory Physiology Research Unit)	+	+	100%
	12. Dr. W. Hitehead (Chemistry) (plus 2 others)	+	-	30%
	13. Dr. McDoewll (Chemistry)--Caud app. - Long Chain Hydro			
	14. Dr. D. Otieno - Pyrthrins - Repellency			
	15. Histology and Fine Structure			5%
	16. Dr. A. Young (Muguga*)	+	30%	+
	17. Dr. T. Dolan (Muguga)	-	10%	-
	18. Dr. K. Cowan (Muguga)	10%	+	-
	19. Dr. A. Irvine (ILRAD**)		10%	+
	20. Dr. S. Shapiro (ILRAD)	10%	-	-
	21. Dr. A. Allison (ILRAD)	ADVICE	-	-
	22. Dr. I. Morrison (ILRAD)	5%	-	-
	23. Dr. M. Murray (ILRAD)	5%	-	+
	24. Dr. S. Black			

*Veterinary Research Department of Kenya Agricultural Research Institute (KARI)
**International Laboratory for Research on Animal Disease