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door dr. T.R. Odhiambo,
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Derde voordracht gehouden ter herdenking van professor dr. J. de Wilde, hoogleraar in de entomologie aan de Landbouwuniversiteit te Wageningen (1954–1982) op maandag 28 mei 1990.

THE ROLE OF FUNDAMENTAL ENTOMOLOGY IN FUTURE CONTROL OF TROPICAL INSECT PESTS

In 1968, Professor Abdus Salam, the 1979 Nobel Laureate in Physics, a preeminent scientist-philosopher who left his native Pakistan more than four decades ago to settle in Europe and commute between London and Trieste doing his research and teaching in theoretical physics in London while presiding over the development of the International Centre for Theoretical Physics in Trieste, gave an account of a young astronomer, Saif-ud-din Salman, who left his far away native city of Qandhar in Afghanistan, a developing country even at that time, to undertake research at the then celebrated observatory at Ulugh Beg at Samarkand in Uzbek, then a technically advances country. Salman wrote an anguished letter to his father in Kandhar, manifestly torn between the intellectual exhilaration he was experiencing in Samarkand, and the strong strings of social belonging which were jerking him home:[1]

"Admonish me not, my beloved father, for forsaking you thus in your old age and sojourning here at Samarkand. It is not that I covet the musk-melons and the grapes and the pomegranates of Samarkand. I lost my native Samarkand and its tree-lined avenues even more and I pine to return. But forgive me, my exalted father, for my passion for knowledge. In Kandhar there are no scholars, no libraries, no quadrants, no astrolabes. My star-gazing excites nothing but ridicule and scorn. My countrymen care more for glitter of the sword than for the quill of the scholar. In my own town I am a sad, a pathetic misfit..."

This anquish is as real today as it was substantive to Salman more than 500 years ago.

The social and economic realities of the developing regions are horrendous, and for Africa they are specially difficult. As a senior fellow of the Institute of Policy Studies based in Washington, D.C., Richard Barnet, stated in early May 1990 after a recent visit to Africa, the illusion that Africa can close the gap in development between itself and the industrialized nations, which formed a cardinal part of the aid philosophy, now appears hopelessly naive:[2]

"... Most of the traditional hardheaded commercial and military reasons for pouring money into Africa's poor countries – keeping communism out of the Third World, making poor countries safe for economic penetration and resource exploitation – have begun to sound oldfashioned or off point. The Soviets are busy at home. Resources turn out to be well distributed around the globe, and, increasingly synthetics can be substituted. Cheap labor is available almost anywhere. Poor people do not make good customers, and not very many of them get rich."

Yet, it is difficult for many of us from the developing regions of the world to simply accept that the present economic situation would apply for ever. One needs to keep alive a realistic hope that one can change a society's destiny if the leadership becomes engaged interactively with the problem. Arne Tiselius, one of Sweden's most thoughtful scientists of any age said twenty years ago:[3]

"I have spoken of values and facts – but are these enough in themselves if we wish to achieve what we hope for? Man is an irrational creature and ever so

convincing arguments may not reach him so that he really becomes *engaged*. Something more is needed to find the way to his mind. Religion, philosophy, literature, and the arts have known some of these ways for centuries."

The insect scientist we are honouring once again through this Memorial Lecture series, Professor Jan de Wilde, was one leading scientist who was truly engaged in matters of scientific discovery, the philosophical essence of value, and a personal drive to enhance human welfare through scientific research. He was a giant among leading insect scientists; and has left imprints of his giant strides everywhere in insect physiology, bee biology, ecophysiological research, and high-level education in insect science. The entomological school he built in Wageningen became a landmark in Europe; and he guided the graduate training of many insect scientists who are now occupying leading research and academic positions in Western and Eastern Europe, China, Japan, and the tropics. Some of the indelible footmarks he left for posterity was the mind and heart he brought to the founding and development of the International Centre of Insect Physiology and Ecology (ICIPE), headquartered in Nairobi, Kenya.

The founding of the ICIPE

In a letter dated 7th October 1966, the Editor of the weekly science journal, *Science*, Dr. P.J. Abelson, invited me to contribute a review article for a series of articles he was then commissioning on the theme, "Science for the Newer Developing Countries". The journal had, over the years, published articles

on this theme on science developments in Latin America and Asia, and Dr. Abelson thought that a similar article on African science was overdue. I took up the challenge, as it provided an excellent forum to paint a perspective of the underdevelopment of science at the time of a fast-moving political independence movement, and at the same time pinpoint the areas of special opportunities. This led me not only to reassess the strong research contribution that the colonial governments made in the areas of tropical agriculture and health, but also to suggest ideas as to how to create a more holistic, science-led social and economic development in Africa based on internal capacities of the region itself, assisted by an interactive international cooperation.[4] The article, having noted the small and fragile scientific communities emerging from the newly independent countries of Africa, espoused the probable effectiveness of establishing concentrated centres of advanced research in critical areas of science.

In October 1969, a Planning Conference was convened in Nairobi to discuss the idea of establishing an International Centre dealing with tropical insect biology and its technological applications, whose main goals would be three related objectives.[5] First, to widen our base of understanding in certain crucial areas of tropical insect biology. Secondly, to investigate new methods of insect pest control, including those arising from endocrinological research. And, thirdly, to foster the growth of the young scientific community in tropical Africa. In January 1970, a further organizational meeting was held, this time in Wageningen, hosted by

Professor de Wilde. It is at this meeting that the final instruments for the ICIPE – its governance, strategic planning, financial tactics, etc. – were concluded in a formal manner. This led to the translation of these understandings into a legal document which was registered under Kenyan Laws, and enabled the ICIPE to aquire its legal personality and entity on 7th April 1970.

Two years later, the *Bulletin* of the American Academy of Arts and Sciences, one of the founding academies of science in support of the ICIPE, was able to state that the lively role the ICIPE was already playing in fundamental, mission-oriented research in tropical insect science was springing to life only because a well-conceived plan and much needed innovative action was successfully accomplished:[6]

"The problems of undertaking basic research in a developing country are well known and oft-recited. Scientists from advanced nations reject the idea of working in developing areas because they fear the loss of their professional visibility; on the other hand, the scientists who are native to these countries tend to receive their training abroad and then find themselves returning to burdensome teaching schedules which leave no time for advanced research, even if the facilities existed..... The results is that the globe is littered with the shells of ill-conceived research institutes that became moribund.... Such a fate is unlikely to befall ICIPE, largely because this novel pattern for a research organization rests upon the coincidence of several important factors. The scientific justification for the establishment of a center for the study of

insect physiology has been evident for some time. Traditional methods of insect control have encountered a number of serious difficulties: most of the pesticides now in use have proved toxic not only to the target pest species but to other living things as well. General poisons like DDT persist in the environment, progressively polluting it to a dangerous level.... At the same time many insects have shown a remarkable ability to develop resistance to these chemical methods of control. As a result, more effective, less dangerous pesticides coupled with a greater understanding of insect biology are urgently needed.... Beyond this fact, the study of insects is one of the most useful ways of approaching problems of a more general significance to biologists and organic chemists. Insect physiology is relevant to many aspects of cellular and sub-cellular biology, including reproduction and sub-cellular communication; it is a valuable field of study for the chemist concerned with hormones, pheromones, and endocrine systems."

The ICIPE seems to have fared productively in its 20 years of existence probably because of four interlocking juxtapositions:

First, the juxtaposition of fundamental research orientation, with problem-solving applied goals;

Second, the juxtaposition of experienced senior scientists, to direct specific areas of research, with young and daring postgraduate students and post-doctoral research fellows, to explore unknown frontiers of insect science;

Third, the juxtaposition of long-term, difficult pest management problems in the tropics, with the urgent concern to bring about a lasting solution; and

Fourth, the juxtaposition of the need to undertake world-class multi-disciplinary scientific research, with the requirement of building up human and institutional capacity in the tropics to sustain scientific excellence and technological relevance.

We believe that the choice of our programme targets has been an important synthesizing forum for ICIPE's relative success compared to other failed attempts to build up centres of advanced insect research in the tropics.

The ICIPE has a modest core programme which has only 5 target pest management areas: those dealing with crop pests (mainly stem-borers, grain legume pod-borers, and the banana weevil); the desert locust; livestock ticks (especially in relation to East Coast Fever); tsetse (particularly in relation to livestock trypanosomiasis); and medical vectors (especially in relation to leishmaniasis and malaria).
These multi-disciplinary programme areas are supported across the board by 5 research support units: chemistry and biochemistry (especially on semiochemicals, chemical ecology, and natural products); sensory physiology (including insect ethology); cell biology (including molecular sciences); biomathematics (especially population modelling); and social science interface (including the issues of traditional knowledge base, interactive technology development and validation).

Overarching these research activities is the high-level training of the future generation of tropical insect scientists, especially at the Ph.D. level, in concert with a consortium of 15 universities in Africa; and the effective networking of many countries in Africa and Asia in pest management technology development and its validation in specific ecosystems.

Human resoure development

Concerns for human capacity building is real and urgent in Africa – even though we realize that a different level of concern is becoming evident in the industrialized world.
For instance, the capacity to produce intellectual talent to sustain scientific research and technological developments in the USA has become a national concern, as reported in the *Scientist* newspaper of 19th February 1990:

"This year, perhaps more earnestly than ever before, the participants will wrestle with the problem of how to ensure that there are enough scientists pursuing the quest for knowledge in the 21st Century. The presidential address will explore a human resources crisis in science; the challenge is to find ways to attract and retain greater numbers of students in science".

The World Bank's "Policy Study on Education in Sub-Saharan Africa", published in January 1988, exposes the challenges of education in Africa very clearly. Some of the findings and suggestions

on the status of higher education in Africa are reproduced here:

"Although substantiation depends more on anecdotal than empirical evidence, African university staff uniformly report that research in their institutions withered in the 1980s. As the financial crisis of tertiary education deepened, research budgets were typically subject to early and severe cuts. The feasibility of offering good postgraduate education also declined, since a significant part of postgraduate (especially doctoral) training involves student participation as apprentices in faculty research and ultimately the solo undertaking of a dissertation project. Stagnation or outright decline in research output and in the capacity to produce future researchers jeopardizes Africa's long-run ability to take advantage of the worldwide advance in science and technology. Africa need not be consistently in the forefront of all scientific and technological advance, and well into the next century a sizable fraction of Africa's Ph.D.s will still undoubtedly be trained in foreign institutions. But the continent nevertheless already needs to increase its capacity to absorb and use new knowledge, and that capacity is in large measure developed through indigenous postgraduate teaching and research programs. For example, advances in genetic engineering and other areas of biotechnology are potentially applicable to problems of plant and animal health in Africa; the impact on production of food crops and on export agriculture could be sizeable. The argument can be extended to human health and even industrial processes– and to such

areas as microelectronics and materials science (ceramics and metallurgy)."

Again:

"The central point is that without African mastery of the underlying science of such developments and the techniques to adapt them to local problems and conditions, the potential benefits to Africa of these advances will likely be lost in large measure and certainly will be late in arriving. World-class university-based programs of both basic and applied research and of postgraduate education are the breeding grounds for the mastery of science and technology. They are the key to sophisticated consumption of mankind's exploding stock of knowledge. They are a necessary condition for African escape from intellectual dependency. Ironically, no African nation can afford to have such programs in the short run, yet none can afford not to have them in the long run."

And again:

"Beyond rationalizing the provision of undergraduate tertiary education, Africa must intensify efforts to develop its own capacity to conduct research and to provide postgraduate education and research training of world-class standards in fields central to African development. Leading candidates for attention in this respect are agriculture and health (including the natural sciences that underlie them), management (including the underlying social sciences), and engineering. Determining which institutions will participate in postgraduate programs of excellence,

in which fields and at what levels, will not be easy for African governments or for their international partners. Questions of international and regional comparative advantage must be squarely faced, since resources will never be sufficient for every country in Africa or even for the continent as a whole to develop capacity at the highest level in all fields and subfields. Ultimately decisions must be made discipline by discipline."

Yet again:

"Research and postgraduate education: Expansion of Africa's capacity to produce its own intellectual talent to fill the highest scientific and technical jobs – in educational establishments, in government and in private sector – is a critical matter to be addressed in building for Africa's future. Here, as with programs for distance education, economies of scale are likely to be important, and these will be difficult to achieve fully within a national context except, perhaps, in a few of Africa's largest and wealthiest countries. The pressing need is for Africa to develop, probably with the support of the international donor community, regional and subregional approaches to these particular goals."

In a later Report, the World Bank's "Long-Term Perspective Study on Sub-Saharan Africa: From Crisis to Sustainable Growth", published in December 1989, provides some sobering statistics, as quoted here:

"To survive and compete in a competitive world in the 21st century, Africa will require not only literate and numerate citizens, but also highly qualified

and trained people to perform top-quality research, formulate policies, and implement programs essential to economic growth and development. Institutions of higher learning must be able to produce, at an affordable and sustainable cost well-trained people in academic and professional disciplines applicable to diverse African work environments.

A new spectrum of scientific and technological knowledge is unfolding outside the continent. Universities in Africa will have to develop a few world-class postgraduate programs in science and engineering if these countries are to have access to the new frontiers of science and technology.

Unfortunately, given the present state of higher education in Africa, the continent is unable to prepare itself to take advantage of the expanding frontiers of knowledge.

One explanation for the shortages in higher skills is the brain drain. *The United States alone had more than 34,000 African students in 1985*, many of whom are unlikely to return to Africa; there are reported to be *more than 70,000 trained Africans who have opted to remain in Europe.*"

"In the longer term, improvements in quality can be realized and sustained by establishing programs or centers of excellence for postgraduate education and research. These could concentrate staff and resources to achieve a critical mass in priority areas. *By establishing such specialized high-quality programs and institutions, African governments would provide able students with an attractive alternative to*

foreign study, create incentives for university researchers to pursue their work on the continent, and thereby also address the serious problem of brain drain."

"Too often government research depends on donor support and collapses when it is phased out. In this light a systematic provision for research and development expenditures of about 1 percent of GDP is essential over the long term."

The serious concern with which human capacity building is viewed, is demonstrated by the involvement pledged by even the banking sector. The African Development Bank (ADB) has recognized it as a large problem; and has included it as a major issue of its investment agenda. The Report of the Committee of Ten on Africa and the African Development Bank entitled, "Current and Future Challenges", published in March 1989, recommends as follows:

"In the second phase, it (the African Development Bank) will endeavour to break new grounds that will reflect some of the wider concerns in its mandate.

Fundamentally, it would reflect the central role of the Bank as an organism of analysis and advice in the field of economic and social policy; and its essential role in the field of economic integration and multinational projects. This will require a concentration on the following areas:

- human and institutional infrastructure
- population growth
- environment and development
- economic integration
- policy analysis, dialogue and advice
- science and technology for development.

In order to address these concerns effectively and comprehensively, we recommend that an *Endowment for Africa* of not less than $500 million be created before the end of Phase I. This Endowment, working closely with the Bank, will facilitate the broadening, and deepening of the bank's activities, as recommended for Phase II, and will thus allow the institution to give further expression to its original mandate. The Endowment will help the Bank become a centre of excellence for analyzing key African development policy issues on all their dimensions and for formulating practical advice to its regional member countries.

This centre of excellence would generally deal with strategic issues of national and international development and focus on the search for effective growth-promoting policies and programmes at the national level; and for practical policies and programmes to assist in the process of economic integration in Africa. The centre will use the results of these efforts to formulate policies and programmes which the African Development Bank as well as other institutions could integrate in the operational programmes which they periodically evolve in support of the development efforts of African countries."

Again:

"We also feel that special emphasis must be put on human resource development. It involves the means of production, awareness and management of environmental problems, raising of living standards, and cultural and human balance. Exceptional efforts are needed in Africa as elsewhere in the world. But at this stage, our joint recommendation favours taking immediate advantage of the reservoir of knowledge which already exists. It must be more thoroughly mobilized in the service of Africa. We feel that the multiple challenges faced by this continent cannot be efficiently met without harnessing all available talent in the effort. New initiatives should also be taken to bring the best of existing energies into a centre of excellence in the service to Africa. This will also attract back to Africa some of its best sons and daughters and inspire new talents, fuelling the enthusiasm of younger generations in both regional and non-regional countries."

Endorsing this ADB strategic thinking is the Independent Group on Financial Flows to Developing Countries, which was chaired by Dr. Helmut Schmidt, former Chancellor of the Federal Republic of Germany. In their Report issued in June 1989, the Independent Group described one of the forward ways open to Africa, in these words:

"There is no region in the world in which the problems of development are as overwhelming and pressing as in sub-Saharan Africa. This is true in terms of population growth, environmental degradation and declining agricultural and food production, but

it is particularly true with regard to the dearth of trained and skilled human resources. Ultimately, the possibility of redressing their situation lies with Africans themselves.

However, without sufficient levels of policy-making, professional, technologies and managerial leadership, this is a responsibility which sub-Saharan Africa cannot bear. Donor countries and multilateral agencies should make special efforts to provide funds for the educational training and qualitative enhancement of African leadership in these and related areas.

Specifically, the OECD countries – with major participation by the surplus countries – should establish a *$1 billion endowment fund* to be administered by the African Development Bank. The proceeds of this fund should be used to assist the development of such leadership in order to create the institutional infrastructure in sub-Saharan Africa so vital to its achieving sustainable political stability and economic growth."

The ICIPE finds this situation grave, in terms of future problem-solving capacities, and has played an important role in fostering and marshalling efforts to support human capacity building in the African continent. Early in the life of the ICIPE, a number of advisory organs were established – each specifically charged with a specialised problem-area, for example the International Committee and the African Committee. The primary responsibility of the *International Committee*, consisting of several academies of science, was to monitor the quality of

ICIPE's research effort and to assure the ICIPE of effective international networking. The International Committee later transformed itself into the ICIPE Foundation. In its final role, the *ICIPE Foundation* sponsored a meeting on Scientific Institution Building in Africa at a symposium held at the Villa Serbelloni, at Bellagio Conference Centre on Lake Como, Italy, from 14th to 18th March 1988. The presentations and discussions led to a striking convergence of views; and the Symposium reached the following far-reaching conclusion:

It became apparent that all participants, from widely differing perspectives and experiences, found they shared a remarkably common perception of the evolution of Science and Technology (S&T) institutions, of their importance, of what had gone wrong with them, and what fresh approach was needed to create an effective S&T institutional capacity in Africa. Although no particular information was especially new or unexpected, the very fact of this convergency of perceptions, shared by African scholars and donor agency representatives, at a time when many donors are evaluating the effectiveness of their programmes and projects, is believed to signal the opening of an important new window of opportunity in African development. Because of Africa's plight, and because the window will not remain open long, it is urgent to re-emphasize the importance of African scientific institutions to the future of economic and social development, and in particular to reorient all levels of education towards creating a science-based African culture.

To this end, it was agreed that the meeting could most usefully contribute to promoting and reshaping support for new approaches to African S&T institutional capacity building...."

Again:

"A number of African universities have built fine science departments and have produced some of Africa's most outstanding scientists. Numerous national and regional research institutes were established in many countries, particularly in the 1960s. The total number of these institutions was considerable, as were the numbers of scientists trained. World-class research was carried out, and is still being carried out, at a number of centres. Subsequently, however, support for universities as intellectual centres weakened, and in aggregate there has been a failure of technical assistance programmes with African governments to create an effective African S&T capacity, particularly in later years, for many reasons. These include, especially, a frustration with the pace of development in the face of new and mounting problems. This frustration led to pressure to focus on solving problems through external solutions, rather than to continue to create the capacity for Africans to solve their own problems, and to look for "quick fixes" rather than long term solutions."

Yet again:

"Africans and African scientists are going through a difficult period. Much of this difficulty is due to global political and economic forces beyond their

control; much also results from their willingness to accept foreign ideas, institutions, and development objectives, which has left them stranded midway between traditions to which they cannot wholly return, and a modern, science-based society at which they have not yet arrived. It has been barely a generation since most Africans gained political independence. They need to gain more time, with assistence form abroad, to overcome present difficulties and achieve their cultural and economic independence. The international scientific community and the donor community have special roles to play in providing carefully sustained support for reorienting African education and for strengthening scientific and technological institutions and capacities."

The principal focus of the *African Committee*, referred to previously, was to relate ICIPE's scientific effort with African needs, and to concern itself with the effective role of the ICIPE in providing Africa with high-level indigenous insect scientists. In the course of its successive annual meetings in several capitals in Africa, the African Committee had the question of postgraduate training high on its agenda. At its 9th meeting held in Nairobi on 8th December 1978, the Committee passed a special resolution, to the effect that:

"The ICIPE, in collaboration with African universities, institutes at the ICIPE Headquarters in Nairobi, Kenya, an INTERNATIONAL POSTGRADUATE COURSE IN INSECT SCIENCE IN AFRICA leading to M.Sc. and Ph.D. degrees. In proposing this programme, the Committee was aware that postgraduate courses in Entomology were available in some African

Universities and could be mounted in others, but it was strongly felt that the facilities available at ICIPE were unique and would make it possible to establish a high standard of international postgraduate course in insect science under African conditions."

The same meeting followed its resolution by establishing an ad-hoc Working Group to work out, in consultation with African universities and research institutions, a curriculum for the proposed postgraduate programme, together with other questions related to this cooperative enterprise.

The concern expressed by the African Committee culminated in a Planning Conference held at Bellagio, Italy from 7th to 11th September 1981. Twenty-two participants representing nine universities and three research institutions in Africa, and institutions and donor agencies from North America, Europe and Australia attended the Planning Conference. After exhaustive deliberation, and on the conclusion of the Conference, the participating African universities and research institutions resolved to establish the African Regional Postgraduate Programme in Insect Science (ARPPIS). They issued a communique as follows:

"We, representatives from Universities and other Institutions in Africa, *recognizing* the great importance of insects as vectors of human and livestock diseases and as pests of agricultural crops which limit productivity, note the need and *endorse* the proposed programme for improved training in insect science through the strengthening of institutions in Africa.

Noting that the number of insect scietists in Africa is inadequate and that the need exists to collaborate in research and training in order to use scarce resoures to full advantage, and *recognizing* the mandate of the ICIPE to develop and promote insect science, especially methods of pest and vector control which would be appropriate in African ecosystems. We *agree* in principle to cooperate in establishing an African Regional Postgraduate Programme in Insect Science through a Collaborative Training Scheme and *agree* that the Programme should commence as soon as the appropriate approvals have been received from at least three University Authorities and satisfactory financial arrangements are assured. The target date for implementation of the Programme is January 1983.

We *agree* also that the ICIPE shall act as Manager for the Programme on behalf of participating institutions."

From a research standpoint, the ICIPE has progressed in developing, modifying, adapting, extending and intensifying scientific and technological information relevant to the control of insect pests in tropical developing countries. Through this progress, the ICIPE has amply demonstrated its ability to excel in these areas, many of which hold promise for making insect control more affordable, safer, more effective, and therefore sustainable and more extensively used. Through ICIPE's efforts, for example, a whole new generation of low-cost, effective, integrated pest management practices are appearing on the horizon to further help resource-poor rural communities.

At its inception, ARPPIS started with seven Participating Universities and ICIPE. It enrolled its first eight Ph.D. students in 1983. By 1990, there are 15 Participating Universities; and 89 students from 17 African countries have entrolled in the programme. Forty of these have successfully completed their programmes at the ICIPE and returned to their countries as lecturers in universities or researchers and practitioners in research and development institutes.

The vision of the ARPPIS programme in 1979 was to offer both M.Sc. and Ph.D. studies. Because of resource constraints and the relatively strong M.Sc. programmes being offered at that time by several universities in Africa, a deliberate decision was made to concentrate ARPPIS on the Ph.D. programme alone. Both the Participating Universities and the ICIPE have achieved a landmark in advancing ARPPIS in a unique partnership in which both the course-work and project work are undertaken at the ICIPE; the universities participate in the student supervision and in the academic governance of the programme, and award the degrees.

Some of the best research ideas, and some of the most aggressive research pursuits, have emerged through the combined efforts of the ICIPE graduate scholars and their supervisors. The need for such interaction is expanding. Indigenous manpower resources for insect pest management at the national level must be increased, hence the graduate education task which lies ahead is enormous.

While existing training through the ARPPIS Programme has been, and is, a matter of pride, the ICIPE has also learned that it must continue to develop information and continue to implement its education programmes, in order to ensure that it can build on the past achievements, and plan further to *meet the needs of the next decade and beyond.*
The enthusiasm and commitment of the ICIPE staff to graduate training has been among the major reasons for the success of the recent past. The intellectual stimulus that this training has returned to the ICIPE staff, enhances the merits of the activity and dictates the need for further development for the future.

Clearly, the research accomplishments that are evolving, and the human resource development building must continue in a comprehensive and well coordinated manner. This should provide the optimal social and political environment needed to enhance in-country recognition of S&T as well as deepen sensitivity as to what insect science and pest management technology can do for the society and its economic development. The building up of indigenous scientific critical mass in insect science is paramount, without which the cost-effectiveness of the efforts of the ICIPE, regardless of how well targetted, will not be optimally realized.

The ICIPE, and the ARPPIS participating universities, have set an enviable record in academic cooperation in building up the beginnings of scientific capacity in insect science in Africa, with more than 40 Ph.D.s already graduated, and a further 45 or so now in session at the ICIPE. However, future demands on this

cooperation will far outrun these successes over the last 8 years. New insights, innovations, management structures, and training programmes therefore need to be set forth to integrate the facets of the existing programme, to enrich them, and to realise the full potential of the programme. It is in search of this new paradigm in graduate training that the ICIPE Management appointed in May 1987 a Task Force on th Future Development of Graduate Training at the ICIPE, led by Professor Lameck K.H. Goma, Minister of Higher Education, Science and Technology, in the Republic of Zambia, and himself a trained mosquito entomologist. The Task Force has made a strong recommendation that the ICIPE, as a centre of advanced research in insect science, have attached to it a semi-autonomous Graduate School, able to award its own degrees. This is a far-reaching innovation, able to link excellence and relevance in research with academic excellence.

The proposed ICIPE Graduate School is still under wide-ranging discussion. But it should be noted that the proposal will *not* transform the ICIPE into a university; that this devise will permit a greater level of innovation in graduate training in Africa; and that it will encourage the creation and sustenance of excellence in graduate education. Furthermore, pioneering examples of this sort can be cited from other regions: the Tata Institute of Fundamental Research, in Trombay, India; the Feinberg Graduate School at the Weizmann Institute of Science, in Rehovoth, Israel; and the Instituto Venezolano de Investigaciones Cientificas(IVIC), in Venezuaela. The debate continues – just as the ICIPE is beginning to make major breakthroughs in pest management technology development. Examples that are becoming

well known are the development of an odour-baited trap for tsetse, which rapidly depletes the vector populations and sustains it at a very low level (of less than 1% of the original population) indefinitely; and of the emerging anti-tick vaccine process for the management of the East Coast Fever vector, *Rhipicephalus appendiculatus*.

ICIPE's fundamental approach can be gauged from its strategic planning for the initiation of the research work on the desert locust (*Schistocerca gregaria*) in late 1989. The fact is that the desert locust has been, for thousands of years, a plague and a natural disaster in the semi-arid Africa, the Middle East and West Asia. They have not been under control, because they have always appeared as a coherent, impenetrable swarm in the horizon, swooping down on the lush, recently rainfed savannah after several years of drought. In the last 60 years, man has met such national emergencies by military-cum-civilian attack groups which include mechanized army units, joined by the air forces of several countries, and thousands of communication and ground support civilian groups. The main weapon continues to be highly poisonous chemical pesticides, given in airspray barrages for flying adults or as baits on the ground for hoppers.

The sight and logistics of the chemical war machine, busy and angry once locust swarms are sighted, gives a false sense of security that modern man indeed possesses the means of annihilating locusts. However, when we begin to carefully analyse the impact of these often spectacular technologies, we find that our sense of security is wholly unjustified in the long run. What our locust management strategy should

be addressing must include the following, if we are to have a sense of accomplishment of our control goal:

- We should comprehend the nature of the locust phenomenon: how they transform from sedentary, grasshopper-like insects to gregarious, marching and swarming locusts
- There should be early-warning systems developed for preparing timely control and rehabilitation measures
- There must be constructed adequate locust measures that deal with emergencies as well as longer-term control, without damaging the environment and causing distress to the human population living in locust-affected localities.

In each case, we find that our present scientific knowledge of and technologies for the control of locusts is inadequate and unsustainable.

This is a remarkable position to be in, since locusts are not new to us. The earliest records of locusts are to be found as carvings on Egyptian tombs dating from the Sixth Dynasty (about 2420-2270 B.C.) at Saqqara, and in the account of the Eight Plague narrated in the Book of Exodus, and dated about 1300 B.C. These swarming plagues have continued to periodically darken our skies and settle on our crops and forage, breaking out of their breeding or recession sites located in remote, usually semi-arid areas, often peopled by scattered, pastoral, nomadic communities. Consequently, locust outbreaks can truly constitute a disaster, as they disrupt the human ecology of these vulnerable communities - by their

sudden appearance, their overwhelming numbers, and the poisonous blanketing nature of the insecticidal sprays that are presently the locust control method of choice. Since 1861, there have been eight major desert locust plagues, the last of which ended scarcely a year ago. Each of these plagues lasted for 7–22 years; each swarm can be up to 1,000 sq.km in extent; rise up to 1,000–1,500 m above ground; and fly for 9–10 hours each day, at a ground speed of 40–60 km per hour.

The losses due to desert locust swarms can be immense. Pliny records that, in the year 125 B.C., locust swarms sighted from the Sahara coused 800,000 people in Cyrenaica to perish, and another 300,000 in Tunisia to die. Actively migrating immature adult locusts eat at least their own weight (2–3 gm) of fresh vegetation each day, and possibly as much as three times their own body weight.[7] Since locust swarms often contain 50 million individuals per square kilometre, a large swarm 1,000 sq. km in extent would consume more than 100,000 tonnes of fresh vegetation each day as they migrate. Their mobility, therefore, makes swarming and migrating locusts a devastating phenomenon. Since desert locusts have a vast invasion area, amounting to 29 million sq. km. affecting 57 countries in Africa, the Middle East and West Asia, they are a pest of vast socio–economic importance little quantified because they largely affect highly vulnerable, voiceless, pastoral and nomadic peoples of these semi–arid and desolate lands.

Is there any hope of long–lasting desert locust control?

The future perspective of locust control

It is our belief that long-range desert locust control technologies will only arise when we know, *intimately*, the behaviour of the locusts and can interrupt the regulatory mechanisms of such behaviour.

The desert locust occurs in two phases: first, the *solitarious phase*, in which scattered populations resident in the permanent semi-arid breeding areas occupy the so-called "recession areas" during drought years; and, second, the *gregarious phase*, in which these scattered populations can breed quickly, within 2-3 generations, leading to vast numbers, which aggregate, march as hoppers, and then swarm as adults, becoming highly mobile, which then travel up to 1,000 km in a week, assisted by winds. Such gregarious locust swarms only arise after favourable rains over several seasons succeed a long stretch of drought years. It is this change over in the physiology and behaviour of the locust that is at the centre of innovative attempts to ground the locust; to make it remain *sedentary*, behaving as a solitarious, *grasshopper-like* population; and to keep it permanently non-swarming and non-migratory. This approach has not been attempted before. The ICIPE has designed this approach as its research centre-piece for a search for sustainable management of the desert locust.

The project is about the chemical ecology of the desert locust, and will be undertaken for the next 5-10 years, in which it will isolate, chemically

characterize, and study the phase–transformation and behaviour–modifying functions of 7 pheromone and kairomone systems:

1. *First*, a set of swarm–promoting pheromone systems, which are crucial for triggering the gregarization behaviour, both in the nymphal stage as well as in the adult; that accelerate and synchronize sexual maturation in the adult; that keep swarms in a migration mode coherent and intact; and which stimulate and concentrate egg–laying within the same field. There seems to be 3 classes of pheromone systems involved in these pheromone–induced behaviour changes:

a. *Gregarization pheromone system* associated with the immediate environment of crowded locust hoppers. This pheromone functions by promoting crowding or grouping behaviour, thus potentiating them to form marching bands – and later, adult locust swarms.

b. *Sexual maturation pheromone system* comprises biochemicals secreted by the male locust at maturity. The volatile pheromone functions by accelerating, and at the same time synchronizing, the sexual maturation of both sexes.

c. *Oviposition pheromone system* stimulates pregnant females to aggregate to a common egg–laying field. Within hours of copulation among swarming locusts or marching females, the females start to search for suitable egg–laying sites. When a pregnant female finds one, it is joined by other

pregnant locusts, sometimes numbering several hundreds, thus depositing their eggs – in a matter of 7–30 hours – in a *common egg-laying* field.[8]

2. *Second*, a set of de-gregarization pheromone systems, which appear to reverse the major effects of the first set of swarm-promoting pheromones. This set may well play the role of the de-gregarization process. There seems to be two classes of such pheromones:

d. *Solitarization pheromone system* which appears to promote seemingly anti-grouping or anti-social behaviour in the nymphal stages.

e. *Sexual maturation-inhibition pheromone system* which acts by inhibiting or delaying sexual maturation in the young adults of both sexes.

3. *Third*, kairomones from host plants, which act as *feeding attractants* or *stimulants*. They may, consequently, influence the behaviour of pre-swarming locust nymphs and young adults by synchronizing the development of these immature stages. Two groups of kairomones have been cited as candidate biochemicals for influencing the behaviour of locusts:

f. *Volatile odours* of host plants, whose specific blends may play an important role in host location and in potentiating the nymphal stages to a gregarious behaviour.

g. *Non-volatile feeding allelochemics* of host plants, which may influence the feeding preferences of the locust.

While some information, obtained in the 1950s – 1970s, provide some clues to the chemical nature of the first group of behaviour-modifying natural biochemicals, we know very little about the second and third groups.

It may be instructive to describe in outline detail our state-of-the-art knowledge of the gregarization pheromone system. It appears that two functionally different sets of pheromonal signals are operational. One set is apparently associated with the atmosphere immediately enveloping crowded locust hoppers, which has been experimentally shown as arising from the faeces of both gregarious and solitarious hoppers. This pheromone functions by promoting the grouping behaviour (and several associated physiological changes) of locust hoppers, and may as a result potentiate them to form hopper bands (and later to swarm as adults). This triggering biochemical may be regarded as a *primer pheromone*, which initiates the physiological and behavioural transformation of the solitarious hopper to the gregarious phase.[9-14]

A second set is apparently associated with the already aggregated locusts, whether nymphs or adults, which functions by maintaining the aggregation state.[15] This biochemical may be regarded as an *elicitor pheromone*. The several attempts made by three different laboratories in Europe and South Africa to isolate, identify, and chemically characterize the gregarization pheromone systems have so far not succeeded in reconciling the quite different results.

In one analytical study, steam distillation of faeces dropped by locust hoppers, followed by solvent extraction and preparative thin layer chromotography, led to the identification of the so-called *locustol* (or 5-ethyl-2-methoxy phenol) as the major active component, as well as smaller amounts of guiacol.[18] This analytical approach could not deal with minor and the more volatile components of the active extract. In a different, and more recent, analytical study, airborne chemicals from locusts at different physiological stages were entrained at a temperature of 0°C; the trapped material was then extracted with a low boiling-point solvent; and the extract analyzed by gas chromatography-mass spectrometry system (GC-MS). Four components were thus identified, three of which were phenol, veratrole, and guiacol; no locustrol was found. It should be noted that even with this analytical method, no components more volatile than phenol could be captured. The ICIPE analytical approach would be to use a very effective trapping-purging technique which has been developed at the ICIPE since three years ago, which does not involve the use of solvents, which often mask the volatile components.
Furthermore, rather than relying on physiological indicators for gregarization which are presently still controversial, such as increase in chiasma frequency in nymphal stages, the ICIPE scientists are developing quantifiable biochemical markers associated with the onset of gregarization, which might be found in the haemolymph, for instance.

It is ICIPE's conviction that the interruption of the gregarization pheromone system, the sexual maturation pheromone system, and the oviposition

pheromone system – which together bring about the rapid and synchronized development of coherent, highly dense locust swarms – acting in concert with the promotion of the solitarization pheromone system and the sexual maturation–inhibition pheromone system, which influence the intensity of solitarization – using both approaches jointly, should assist the maintainance of locust populations under relatively sedentary, grasshopper–like life–style. It is our dream to accomplish this goal, which will lead to the continued existence of pheromone–maintained solitarious locusts as natural herbivores in Africa's semi–arid breeding grounds, and in this way continuing their important role as a participant in the dynamics of the savannah ecosystems, without periodically breaking out into locust plagues.

Prospects

Fundamental mission–oriented research on the major tropical insect pests that have been part of the long–term research agenda of the ICIPE is beginning to bring about a revolution in long–term, ecologically acceptable, technologically effective pest management technologies.

Our move to be concerned with a holistic view of our target insects, a view which was vigorously fostered by Jan de Wilde, is at the basis of our emerging technological successes. He was not simply a research scientist, purely concerned with the experimental design and the disciplinary perspective that the research data will give him, he was a creative

scientist of the type that Carl Sindermann (1985) has described so vividly:[17]

"The scientist ..... is far more than a laboratory-bound stereotype. His or her career destinations are diverse, interesting, and absorbing, but the base remains the same – productive, innovative, relevant research and teaching. Beyond this base ... are career extensions ... whether they be managerial, political, or entrepreneural, are most readily available to excellent scientists – those who have established credibility and have succeeded in the practice of science."

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