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**SCIENCE AND
TECHNOLOGY
FOR THE RURAL
FARMER**

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**ICIPE
1977**

**THE INTERNATIONAL CENTRE OF
INSECT PHYSIOLOGY AND ECOLOGY**

P.O. BOX 30772, NAIROBI, KENYA

**THE STATUS OF INSECT SCIENCE
IN THE TROPICAL WORLD:**

**SCIENCE AND TECHNOLOGY
FOR THE RURAL FARMER**

By

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**Third Lecture 8th June 1977
ICIPE Research Centre, NAIROBI**



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THE STATUS OF INSECT SCIENCE IN THE TROPICAL WORLD

THE SERIES of ICIPE Annual Public Lectures are devoted to the general theme of "The Status of Insect Science in the Tropical World". In it, the ICIPE Director examines, each year, the problems and progress of insect scientific research in all its many manifestations, but especially in the way it contributes to national development in Tropical Africa. The ICIPE is interested in investigating new frontiers of insect sciences, in using this knowledge to design novel methods for pest control over a long-term basis, and in building up the capabilities of the African scientific community in meeting these challenges.

On Wednesday, 4th June 1975, the inaugural lecture in this series was delivered on, "This is a Dudu World". The second address, delivered on Wednesday, 9th June 1976, Professor Thomas R. Odhiambo explored the problems associated with "National Scientific Capabilities. In this third lecture, on "Science and Technology for the Rural Farmer", Professor Odhiambo is concerned with the technological problems facing the small farmer in the rural community in the tropics, and the dearth of scientific knowledge and can help him to overcome these deficiencies.

SCIENCE AND TECHNOLOGY FOR THE RURAL FARMER

It has been known for some time now that whereas the American farmer produces food to feed himself and 29 other people, and the German farmer likewise provides food for 25 other people, the African farmer produces food for only 1.5 other people. The yawning gulf between the productive performance of the two sets of farmers—the technology-loaded farmer in the developed, temperate countries and the tradition-bound farmer in the developing, tropical regions—is the focus of a great deal of debate by policy-makers, statesmen, and development planners. The debate is an important one because over 70% of the human population in tropical Africa lives in a rural setting; and it should therefore be expected that the bulk of the national income should derive from agricultural production. Yet, excluding the OPEC countries, the developing countries' share in world trade was only 31.6% in 1950, it was 20.4% in 1968, and is presently hovering around 15%.

Undoubtedly, a factor in the rather dismal performance of the developing countries in competitive world trade is the generally unfavourable rate of exchange for their agricultural raw materials, a nettle that the North-South dialogue in Paris has been attempting to grapple with during their earlier and current sessions. Although political economists have suggested a number of stratagems for over-coming this imbalance—such as pegging the price of agricultural products to the price of finished industrial products, or the establishment of a price stabilization fund, or the building up of a buffer stock—there is no question that developing countries must also find means for the expansion of their agricultural productive capacities. They need the additional national income from enhanced productivity to cover their import requirements (often of capital goods), to bring a modicum of improvement of the living standards of their people, and even to service their galloping external debts.

What then are the avenues open for bringing about this near agrarian revolution in the developing, tropical countries?

I believe that in Africa, one has to look at the 70% of its population—the rural community, the preponderant majority of whom have very small farms of less than 2 hectares. As the saying goes, “Farmers are the founders of civilization”. How far has the African farmer succeeded in laying the foundation of African civilization, and what are the special circumstances in which he works? Ocol, the cynical husband of the tradition-bound Lawino could not have put it better when he lamented¹:

*“You scholar seeking after truth
I see the top
Of your bald head
Between mountains of books
Gleaming with sweat,
Can you explain
The African philosophy
On which we are reconstructing
Our new societies?”*

THE GOALS OF THE SMALL FARMER

An essential element in the critical examination of the circumstances of the African rural life is that the small farmer is not so much concerned with national production goals but rather with the stability of his agricultural production system. While our own concept of modern agriculture conjures up a picture of endless stretches of sugarcane, wheat, maize, or tea from one horizon to another, our traditional small farmer in Africa is concerned with assuring his family of food, fuel, and building material throughout the year.

We call this traditional agricultural system "subsistence farming" or "mixed cropping system". It calls for limited capital outlay, it uses limited agricultural inputs such as fertilizers and pesticides, it employs abundant human labour and little of animal or mechanical power, it utilizes simple farm tools and little modern machinery, and it commands low returns in monetary terms. Some people even say that it is an untidy system, which is difficult to improve with modern technology. It is all these things, and it appears untidy—but I would argue the point about the impossibility of improving it by using modern technology.

I believe the point being made here is that conventional technology and wisdom cannot improve it—but there is no reason to believe that a reorientation of our scientific research cannot understand the system and improve on it. We shall return to this question later during this discourse. The principal point that I wish to make is that the tropical peasant farmer, whether in Africa or South-East Asia, has adopted agricultural practices over the 10,000 years of man's agricultural revolution, which best fit the resources—both human and physical—at his disposal. His objectives are clear:

He wants to stabilize his agricultural output and minimize risks by having mixed cropping system. He is not primarily interested in maximizing his yields of individual component crops, but he is certainly concerned with the production of food staples in adequate quantities for his family's needs, a variety of vegetables and fruits for their requirements, and a range of novelty items such as condiments and plants for herbal medication.

He is anxious to improve his general way of life and enjoy a fuller existence, just as anybody else, by having the means for purchasing the things he cannot obtain from his own agricultural enterprises (such as clothing).

If we have learnt anything about tropical science in the last 15 years or so it is that in the special environmental circumstances of the tropical world, our vast store of scientific knowledge—based very largely on the research advances in the northern temperate regions over the last 300 years or so—can only be applied to the solution of problems in the tropics after considerable modification, and that in many important tropical cases entirely new phenomena must be tackled by completely novel research strategies.

One such crucial area, needing an imaginative new research approach is that of modernizing the agricultural practices of the small farmer in tropical Africa, assuring him of a stable and diversified production, and giving him incentives for a more satisfying rural life.

Yet, many thoughtful people dismiss this thesis as not only visionary but impractical. The logic of their argument seems to march inexorably to what seems to be a most reasonable conclusion: since it is expected that the world population will double by the end of this century, efforts to feed and clothe this vast population will increasingly force agriculture towards the comparative simplicity of mono-cropping systems, and reject the seemingly unity and under-productive mixed cropping of the tropical peasant farmer. This view has been forcefully enunciated recently by Stephen Wilhelm², when he stated:

"... We cannot do as primitive cultures did and still do, except in our home gardens, namely, grow a jumble of different food plants together in small plots... or even as the Aztecs did, plant corn and beans together, the beans climbing the corn. For the sake of efficiency of all operations and for the essentiality of high yields, modern agriculture is built around genetic uniformity, monocrop agriculture, and machine harvesting".

And Ocol in his lamentations of traditional Africa, cries his anguished advice to his tradition-bound wife Lawino in support of this enunciation¹:

*"Weep long,
For the village world
That you know
And love so well,
Is gone,
Swept away
By the fierce fires
Of progress and civilization!"*

But is this necessarily true? Is there only one avenue that development-oriented science and technology must follow regardless of any special environmental circumstances, and ignoring the entire cultural and economic milieu of a people? I do not believe so; and there are straws in the wind that presage a dawning realisation that we are abysmally ignorant of tropical agriculture and other aspects of tropical science. One of these straws is the currently popular ideology of "intermediate technology" or so-called "appropriate technology".

APPROPRIATE TECHNOLOGY

The ideals behind appropriate technology are exemplary, and recognize the fact that the great majority of the population of the developing countries live in the rural setting and occupy themselves in agricultural pursuits. They also take into consideration the phenomenon of the rapidly increasing rate of population growth in these countries. The practitioners of appropriate technology have therefore adopted a number of strategies:

They have laid strong emphasis on labour-intensive processes, in order to provide employment to the rapidly increasing population in the developing countries

They have laid equally strong emphasis on rural development as their major goal, using equipment which is adapted to the competence of the rural community

They have aimed at fulfilling the agricultural needs of the countries concerned, since the majority of the population live in the rural areas

They have taken account of the poor credit facilities normally available to the rural community

They have aimed at utilizing locally available resources (both human and material) for meeting the needs of the people, for example in constructing dwellings that meet modern standards but yet are still comparatively cheap

They have adopted, as a philosophy, the integration of the large rural community into the national production systems, by for example rational mechanization of agriculture and the establishment of agro-industries in the rural areas for the processing of agricultural products.

The ideals of the appropriate technology practitioners have unquestionably been geared to serve some critical needs of the rural community in the tropics, especially in the fields of agricultural enterprise. However, the success in translating these ideals into the practical realities of the complex life and expectations of the small farmer in the tropics has been minimal. An illustrative example of this dismal failure has been in the provision of farm equipment to ease the back-breaking burden of the small farmer and to enable him to overcome the seasonal shortage of

farm labour at peak periods of labour requirements—at planting time, weeding, and harvesting.

Not only have the machines been clumsy and poorly designed, they have also proved expensive to maintain and service. Indeed, all that has happened in most cases is that a machine originally developed for temperate agriculture in an industrial large-scale farming community, has been miniaturized and made with cheaper materials using conventional technology. It is this type of approach to technology meant to be appropriate for the tropical farmer that has increased scepticism for the efficacy and appropriateness of intermediate technology. It is this self-same failure that is beginning to diminish enthusiasm in the developing world for the new theology of "transfer of technology".

One vital factor of production that the tropical farmer has in short supply is power: by and large he has no assured source of cheap and plentiful diesel oil and other oil fuel products; he has generally no coal deposits to exploit; and his erstwhile sources of fuel from wood products are dwindling rapidly. A second vital circumstance for the tropical farmer is that his production unit is generally extremely small, of less than 2 hectares. Consequently, the designer of agricultural machinery for the tropical farmer must consider these two crucial problems in his design scheme: to break away from conventional technological practices and design agricultural equipment which depend on non-conventional sources of power, and to design machinery that can efficiently and economically work within small production units.

From West Germany, Professor Hans A. Havenmann³ has stated these concerns clearly and pithily:

"The predominating trend in modern technology towards larger production units, above all in process engineering . . . represents a serious obstacle to the industrialization of over-seas areas.

The important task is to go beyond the level of mere adaptation and to develop a conception of processes which operate economically even at low capacities. This is perhaps the most important of the problems confronting tropical technology".

An approach that Havenmann³ and his Indian colleagues considered recently in Bangalore was whether they could replace the piston-powered internal combustion engine (which consumes a

large amount of diesel and other conventional fuels) by a more appropriate engine for the tropical user without access to oil. Their first approach was to consider an external combustion engine, powered by solid fuel, such as wood, charcoal, or crop remains. Although this was indeed feasible, in the form of small steam engines for working irrigation machinery, it did not take into consideration the acute shortage of water and forest products in most parts of the tropics. They, therefore, turned to an entirely different approach to the problem—to designing, testing, and developing a hot-air engine to replace the diesel-powered internal combustion engine.

Their most successful model consisted of a compression cylinder, in which air was brought to a very high temperature in a heat exchanger, which itself had been brought to an intense heat from the outside by hot combustion gases. The hot air in the compression cylinder was then allowed to expand into a working cylinder, thus releasing energy. Subsequently, the air, still at a high temperature, could be used as part of the combustion gases for the heat exchanger. The power output from this hot-air engine was considerable, as shown by extensive theoretical investigations as well as from practical testing. The significance of this entirely original technological development can be seen from three facets: firstly, that while one must adhere to the known physical laws of nature, one can also circumscribe his problem by spelling out special circumstances (in this case, lack of conventional sources of fuel) as a means of defining the solution required for a technological problem; secondly, that the tropical environment presents a wide field for novel research and development efforts for uniquely relevant tropical problems; and finally, the tropical environment is not "exotic" in the sense of being peripheral, it offers challenges that need to command the best techno-scientific talent available in the world, and that tropical problems are very central to the world as a whole.

If this philosophy were to be put into practice insofar as understanding and further developing the mixed cropping system of the small tropical farmer is concerned, we find ourselves at a real dilemma.

STABILITY IN DIVERSITY

On the one hand, we find that the present farmer finds it hard to bring new science and new technology into his traditional system:

The plant breeder has always chosen his improved cultivars of crops by assuming that his material will be incorporated into a monocrop farming system; the agronomic environment of all the present high-yielding varieties of rice, maize, wheat, root crops, plantains, soybean, chick pea, sorghum, and many other food crops, as well as those of industrial crops such as cotton, pyrethrum, and tea, are those that favour a monoculture; there are no cultivars that have been specifically selected for the farmer who practises mixed cropping

The small farmer has no financial resources to underwrite the agricultural inputs (such as fertilizers, herbicides, and insecticides) which the agronomist tells him he needs to obtain higher productivity on a sustained basis

Mixed farming makes it problematic to mechanize his agricultural operations (such as weeding and harvesting) using the currently available farm machinery.

On the other hand, we find that mixed cropping in the tropics has some critical advantages for the small farmer who has few physical resources at his disposal:

The mixed cropping system constitutes for him an insurance against crop failure (whether these are due to adverse environmental effects, disease, or pests)

It provides a steady supply of a range of foodstuffs throughout the year, and gives him an assortment of items of food, fruit, fibre, medicines, and building materials that he would otherwise have to purchase

It involves a built-in rotation, in which compatible components of the cropping system derive nutrients at different levels, thus making this system highly productive in terms of the entire unit area

It provides continuous cover for the soil throughout the year, and thus acts as an important element of soil conservation of the very fragile tropical soils

It provides a reserve pool of potentially useful germplasm from the wide range of plants normally constituting a mixed cropping conglomeration in any given area.

There are few researchers or institutions that have tried to investigate frontally the very complex agro-ecosystem that mixed farming is. One of these very few is the International Institute of Tropical Agriculture (IITA), in Nigeria. Its main objective is, in the words of Bede N. Okigbo⁴:

"..... The development of improved permanent food production systems that maintain soil fertility and consistently high yields in addition to being economically viable, socially and culturally acceptable, within the abilities of the small farmer and adapted to the different ecological conditions within the humid tropics."

In essence, what the IITA is attempting to do is to make the system less untidy, to find out how it works and what makes it such a successful system for a dependable and diversified crop production system in the tropics, why it is the best system for the small farming units, and how to bring new technology to modernize it—and therefore make it more efficient and respectable.

In other words, how does one take the bugs out of this traditional tropical system?

ECOSYSTEM PEST RESEARCH

In fact, there are very few real bugs on plants under the mixed cropping system. For instance, research at the International Rice Research Institute (IRRI), in the Philippines, has demonstrated that intercropping of maize with other crops (such as mung bean, soybean, and groundnut) has considerable advantage in pest management with the result that the yield of maize is much higher than when it is grown alone in monoculture. Indeed, under intercropping conditions there is dramatically less downy mildew attack and few maize stemborers (Table 1); and the infestation by weeds is almost negligible (Table 2).

There may well be very good biological reasons why this apparent anomaly exists in the field of mixed cropping. As Jermy⁶ aptly observes, most phytophagous insect species are rare in natural plant communities, and they may even be considered extremely rare in comparison to the potential plant-food available to them. Furthermore, as has been inductively concluded by several authors before⁷, most plants in their indigenous locale are resistant to most resident pathogens. Consequently, in the evolution of plant life, it is assumed that natural selection will have weeded out the most susceptible plant individuals and varieties, thus leaving to develop further the relatively resistant varieties. A classical illustration of this little known principle is to be found in the interesting story of the American species of grapes (*Vitis* spp.).⁸ In mid-nineteenth century, plant explorers found that these species were highly resistant to the grape bug, *Phylloxera vitifoliae* (Fitch), in contrast to the European species (*Vitis vinifera* Linnaeus) which proved highly susceptible to phylloxera bugs, so much so that this knowledge was employed in the grafting of European grapevines onto the phylloxera-resistant rootstocks from North America. This strategy formed the basis for the control of this important grape insect pest that is still in practice.

Ecological studies have shown that increasing the plant diversity of the agricultural ecosystem increases the chances of maintaining its pest population at relatively low levels. That seems to be an established fact, as has already been demonstrated at IRRI⁵. What has still to be established is the mechanism by means of which

TABLE 1
COMPARISON OF MAIZE STEM-BORERS ON MAIZE WITH OR WITHOUT GROUNDNUT INTERCROPPING (IRRI, 1972 West Season, at 56 Days After Planting)

Maize Population (Plants/Hectare)	...	...	...	40,000	40,000	20,000	20,000
Groundnut Intercrop	...	...	...	Yes	No	Yes	No
Border-infested Plants (%)	...	...	...	30	86	21	60
Borers (Number/Plant)	...	...	...	0.4	2.6	0.4	2.0
Feeding or Exit Holes (Number/Plant)	...	...	...	0.5	3.1	0.5	2.1
Feeding Tunnels (Number/Plant)	...	...	...	0.4	2.7	0.5	2.0

Source: Richard R. Harwood⁵

TABLE 2
MEAN COMPARATIVE GROSS RETURN FOR MAIZE, MUNG BEAN, AND MAIZE/MUNG BEAN INTERCROP SYSTEM (IRRI, 1973 Dry Season)

	Gross Return in U.S. Dollars/Hectare		
	No Weed Control	With Weed Control	Increase (%)
Maize alone	194	366	88
Mung bean alone	371	438	18
Maize/Mung bean intercrop	504	586	16

Note: Weed control was effected by butachlor at 1.5 kg/hectare active ingredient

Source: Richard R. Harwood⁵

this desirable pest status has been achieved. Some biological control specialists have hypothesized that it could be that the mixed-cropping ecosystem preserves and perpetuates a diversified population of natural predators and parasites⁹. But the truth of the matter is really that we are quite dynamics, under the mixed cropping ecosystem.

A circumstance of our present pest population management system is that it is dominated by the concept of controlling a single dominant pest on a single crop—and treating each individual pest species in isolation from one another. It is only in a few cases that a systems approach has been adopted for tackling the management of a number of key pests invading a single crop. One of the most advanced illustrations of this systems strategy is that on cotton in California.¹⁰ A University of California team has used a systems analysis and computer model of the cotton ecosystem to gain an understanding of systems interactions and to predict the result of any methods applied for pest control over a known time horizon. This is certainly a forerunner of a systems approach for the management of a variety of pests on a single crop grown in a monoculture. It still leaves the crucial problem facing the small tropical farmer trying to make more efficacious pest management under mixed cropping ecosystems—that of controlling a variety of pests attacking an assortment of crop species in small, scattered farming units, found throughout most of the year. Insect science at present is nonplussed and ignorant of the basic knowledge required to understand this unexplored situation, and technology is silent on what control strategies one could even try.

A first principle in war is to know thy enemy. As the Book of Proverbs in the Holy Bible states:

"A wise man is strong

Yea, a man of knowledge increaseth strength For by wise counsel thou shalt make war. . . ."

It seems to me that one of the greatest challenges facing the tropical insect scientist is to start intense research into a thorough understanding of insect behaviour, population dynamics, and pest situation of the diverse insects favouring the mixed cropping ecosystems.

PESTS FOR THE SMALL FARMER

I believe that the ICIPE should accept this challenge, so obviously part of the tropical environment. The ICIPE can only make a significant dent on this complex problem by first identifying the biological questions at the small-farmer level, and then mobilizing its scientific talent, both at the ecological and experimental level, to understand the ecosystem relationships and interactions, and the silent fights that are going on between plant-and-plant, plant-and-insect, insect-with-insect, and the complicated biotic and physical factors that make this diversified ecosystem more attuned to tropical nature than the grossly simplified agro-ecosystem of monocrop culture.

One may well say that such an effort is almost daunting. And he is undoubtedly right! He is also right when he can see further on and opine that the control strategies that may well arise from such novel research effort will certainly be of a very sophisticated type, which only professional insect scientists and technologists will be able to put into practice and monitor. But if, indeed, agronomic research does modernize mixed cropping systems in the tropics to an enhanced level of balanced diversity in stable production, then we will have little option but to abandon our present blundering, scientifically archaic, scorched-earth techniques for pest management. As Dr. John J. Mckelvey, Jr., of the Rockefeller Foundation has said so aptly in relation to the oft-repeated policy for the extermination or eradication of insect pests¹¹: the idea of pest extermination is "an idealistic, arrogant goal that we (a biological species ourselves) know full well will be next to impossible to achieve".

The present practice in assessing the pest status of a crop insect is to compute its economic injury level as a prelude to launching control schedules if it proves to be an important source of yield losses. Yet, it may turn out eventually that what we should search for is not so much economic injury level but rather the ecological injury level. One illustrative example will suffice.

The present conventional wisdom of the crop-oriented international agricultural research centres, and many other recent agricultural entomology groups in Europe and the Americas, states that the simplest and cheapest method for the control of the major

diseases and pests of the staple crops is through the selection, improvement, and release of improved cultivars. And so they are right! However, we do know now, from recent experiences with rice, wheat, beans, maize and other crops, that whenever crop varieties resistant to particular insect pests have been developed and released, the self-same insect species have fairly quickly developed biotypes that can attack previously resistant cultivars, especially if the resistance has been of a monogenetic type.¹² The critical point that I wish to stress is not that biotypes have usually eventually appeared that can turn resistant crop varieties susceptible, but that the plant breeders and their pest scientific colleagues have concentrated on a scorched earth policy of insect exclusion or extermination (by developing highly resistant varieties) rather than adopting a policy of having a weakened and ineffective enemy (by developing tolerant cultivars).

Tolerance implies that the hostplant possesses the ability to grow and reproduce, and to repair the injury caused by its insect population, while supporting a population approximately equal to that found on susceptible varieties.⁸ While we do not as yet know the physiological and biochemical components that are fundamental to the phenomenon of tolerance to insect attack, we do have some preliminary idea that tolerance is a much more effective long-range element of an integrated approach to insect control. So far, no biotypes have been isolated from tolerant crop cultivars; and the prospect is that this is a much more viable approach to pest management than the high-resistance strategy.

PROSPECT

I have tried to show in this short address the challenge that awaits anyone ready to take up the crucial question that dominates our increasing concern for the majority of the tropical human population—the small farmer, and his mixed cropping tradition. One often forgets that man is a very recent experiment in nature; and that of his approximately 10 million years of existence in this world, he has only devoted 0.1% of his tenure of this earth to agro-industrial experimentation and technology. Anybody who cannot appreciate that we have still a long way to go in our research and innovation—a very long way indeed—will certainly miss a most exciting involvement in the near future, particularly in the rich and diversified tropical world.

*"Through wisdom is an house builded;
and by understanding it is established:
And by knowledge shall the chambers
be filled with all precious and pleasant riches."*

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