I.C.I.P.E. SCIENTIFIC MEETING

MULTIDISCIPLINARY APPROACH TO PEST MANAGEMENT AND THE AFRICAN FARMER

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ABSTRACT

Ecological consideration indicate that traditional agroecosystems involving mixed cropping and genetic diversity among crop species are relatively more stable than modern agroecosystems. Modern food production technologies involving more uniform crops over wide areas, use of more costly inputs and associated pest problems are ecologically less stable. With population pressure, greater pressures on the land and shortening of periods of natural recycling of nutrients reduced yields and loss of soil fertility occur. This calls for introduction of modern farming techniques of the 'green revolution' type. Yet the experience of developed countries in about three decades of over-reliance on chemical pestcides, the development of resistance in target species, and environmental hazard of pesticides require caution in development of pest management control programs. What is needed is a program of integrated control or effective pest management as part of an overall natural resource management. This necessitates greater cooperation and interaction among scientists in various disciplines in the study of

the environment, tropical agroecosystems, and development of a range of compatible pest control methods within the means of the farmer, economically and technologically acceptable, and adapted to various agro-ecosystems. All these require (i) changes in biological education and training, (ii) better communication among scientists and the public, and (iii) provision of better advisory services to government policy and regulatory agencies.

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INTRODUCTION

The world's major problems consist of the problems of limiting the rapidly proliferating population, producing enough food for billions of mankind, prevention or reduction of the adverse effects of technology on environmental quality, and limitedness of mineral, energy and other non-renewable resources. In the tropical Africa, the most pressing problems today consist of the problems of producing enough food for the very rapidly growing population, high rates of illiteracy and ignorance with the resultant under-development and inability to apply science and technology to narrowing the gap between the developed and developing countries. In most countries of tropical Africa, the annual rate of population growth ranges from 2 to slightly above 3 percent while that of growth of food production may vary from negative to under two percent. In his effort to produce food and other plant products to satisfy the needs of mankind, the farmer faces serious problems brought about by modernization and rapid social and political changes. Lack of scientific knowledge limits his ability or the means at his disposal for the manipulation of the environment. Although he has made some advances in the production of plant products for export and feeding the factories of developed countries, he is increasingly unable to produce enough food for himself, his family and the increasing non-farming population. In the food production farming systems, the era of his reliance on natural processes of nutrient recycling for the maintenance of soil fertility is virtually coming to an end because of drastic shortening of the period of bush or planted fallows as a result of population pressure on the land. In this effort to produce enough food, one of the most serious constraints is that of crop losses due to the activities of various pests in the field, in storage and in processed products.

Adoption of modern pest control measures which rely heavily on regular and sustained applications of chemical pesticides has to some extent been achieved in plantation crops such as cocoa but much less in food crop production in tropical Africa. In food crop production, the African farmer relies on luck by not practising any control measures, physical methods relying on human power such as hand picking, appeasement of evil spirits by charms and related superstitious practices, and on natural methods the mechanisms or existence of which he is unaware or able to manipulate. Moreover, the failure of scientists and farmers in developed countries to achieve complete eradication or sustained reduction of crop losses by over-reliance on chemical pesticides to the exclusion of old and other tested methods since the early 1940's, the environmental hazards of pesticide residues, and development of resistance in pest species exposed to biocides, call for caution in the development of pest control strategies for food crops in the tropics. This caution is all the more necessary considering the additional health hazards of misuse of chemicals by illiterate farmers who are persistently being pressured to buy and use pesticides by manufact-

To our forefathers as to those of the present generation in developed countries one or more centuries ago, traditional husbandry in the absence of high population pressure involved a sense of holding the land and its resources in trust for future generations and treatment of soils and crops with care so that they will continue to be fertile and sustain high levels of productivity. Much of this good sense of good husbandry in time tested traditional agriculture has been lost in an effort to attain rapid increases in the amount of food required by billions of human beings (Springett, 1973).

NEED FOR ECOLOGICAL APPROACH TO PEST MANAGEMENT IN THE TROPICS

As indicated above, the limited success of exclusive use of pesticides, its attendant problems of resistance of target species, and the present concern about environment (especially in developed countries where most of the knowledge and technology for the solution of these problems abound) requires that we do not rush into their introduction into the tropics without further study and experimentation. Experience has shown that technologies developed in temperate countries cannot without some elements of risk, directly and safely adopted as replacements of traditional practices. This calls for an ecological approach to pest management which takes into account the observation that under natural conditions, ecological equilibrium or balance exists in any given ecosystem among the primary producers, consumers, predators, decomposers, etc. at various energy levels and between living organisms and their environment. Each ecosystem which is a well defined area of land or water possesses specific environmental qualities and characteristic flora and fuana (Springett, 1973b).

A given ecosystm attains a measure of stability through successive evolutionary processes. The African farmer in traditional agriculture not only in the bush fallow cycle but also in mixed cropping attains certain degrees of diversity of species and ecological stability approximating those of natural ecosystems. At the end of each farming cycle the land reverts to bush and finally to forest if given enough time. During the cropping cycle diversity is maintained by the genetic diversity among mixtures of indigenous varieties of a given crop species which is grown together with several other crop species with varying amounts of risk resulting from pest damage, and adverse environmental conditions. But low productivity, decreasing yields, persistent weed growth, soil erosion and continuing loss of soil fertility due to population pressure and shortening the periods of fallow in traditional agriculture have ushered in the desire for improvement of agricultural production techniques by introduction of 'green revolution' technology into the tropics.

This would result in the development of modern agroecosystems of marked instability and immaturity (Smith, 1972, Springett, 1973b). The 'agroecosystem' like the natural ecosystem of the classical ecologist has been defined by Smith and Reynolds (Adkisson, 1969) as ' a unit composed of the total complex of organisms in a crop producing area together with the overall conditioning environment and as further modified by the various agricultural recreational and social activities of man'. Modern agroecosystems of the "Green Revolution" type involve immature and unstable ecosystems resulting from (a) growing of uniform crops of narrow genetic base often selected with marked emphasis on high yields, (b) monocropping of large areas often with only a single variety at least within a given season (c) use of modern costly inputs such as pesticides, fertilizers and machinery often beyond the means and competence of the traditional African farmer and (d) use and management of irrigation water thereby creating artificial environments with their special pest problem (Smith, 1972). The traditional agroecosystem of mixed cropping alternated with fallow periods allows the ecosystem to advance with each season or period of the cycle to greater complexity towards a more stable state. In modern agriculture this stability is resisted in the opposite direction by the use of inputs (herbicides, fungicides, various procedures of cultivation etc.) all of which are designed to produce a clean crop, reduce variation in growth of crop species and productivity (Springett, 1973b). Fertilizers are by necessity in permanent agriculture used as substitutes for natural decomposition products and recycling process in traditional agriculture. While extreme, sometimes unscientific, views that give undue emphasis and attributes to organic gardening are unacceptable, consideration should be given to the fact that decomposition products as organic matter in tropical soils perform not only functions connected with improvement of soil texture and supply of nutrients but also in contributing significantly to the colloidal fraction and the exchange complex.

Above considerations make it imperative that in tropical agriculture, perhaps much more so than in temperate agriculture where natural changes and processes are slower, greater interest should be shown in integrated pest control or better pest management as part of an overall strategy of resource management which would enhance the viability of the agroecosystem and the environment.

INTEGRATED CONTROL OR PEST MANAGEMENT

Integrated control according to FAO and Smith and Reynolds (Corbet, 1973) is a pest management system that 'utilizes all suitable techniques and methods in as compatible a manner as is possible and maintains the pest population at levels below those causing economic injury'. It involves basically a containment strategy rather than an eradicative one and employs the idea of maximizing natural control forces and utilizing any other tactics with a minimum of disturbance and only when losses justifying action are threatened (Huffaker, 1972). The main objective of integrated control or pest management is to keep pest population at a mean level below that at which economic injury occurs, with a small range of numerical fluctuation (Ito, 1973). It relies on the analysis of the biological economic systems of pest control and crop production (Huffaker, 1972) for the creation of new agroecosystems in which natural control agents combine harmoniously with the limited use of artificial agents such as chemical insecticides, fungicides, herbicides etc. (Ito, 1973). It requires a knowledge of significant factors acting on complex real pests and potential pests and other natural enemies and the interactions among themselves and processes of crop production. In short, it requires a knowledge of population dynamics.

Integrated control according to Way (1973) differs from other methods used in pest management in the deliberateness of the activity and conscious attempt to blend and harmonize chemical and biological techniques. The range of methods involved include (a) cultural control, (b) physical and chemical methods, (c) use of plant and animal resistance (d) genetic control (e) use of natural economics, (f) use of natural and synthetic attractants and repellants,

(g) use of hormonal chemicals (h) use of selective, non-selective and biodegradable pesticides and (i) preventive and regulatory practices (Huffaker, 1972). Two or more of these methods may be compatibly employed in any one situation.

MULTIDISCIPLINARY NATURE OF ECOLOGY

Agriculture is a bioeconomic activity and by its nature makes the farmer more of a jack-of-all-trades than other professions. Similarly, integrated control which involves a range of methods or technique is based on knowledge of fundamental or classical ecology which in turn depends on applications of knowledge from the basic sciences, namely, chemistry, physics, biology, geography, mathematics and even history. Classical ecology may be defined as the study of organisms in relation to their environment. The environment in turn is the totality of external forces and influences which affect the life of an organism (Billings, 1969). The environment possess space and time dimensions with varying gradients in different directions and changes through time. The environment also has physical and biological components; (1) the physical components consisting of energy (radiation, temperature and heatflow) water, atmospheric gases and wind, fire, gravity, topography, geological substration and the soil, and (2) biological components consisting of green plants, non-green plants (decomposers, parasites and symbionts), animals, and man. All these components of the environment interact with each other in varying degrees through time in a given location.

Ecology is by its nature an integrative science which draws its information from the biological sciences (genetics, taxonomy, physiology, etc.), soil science, climatology, geology, physics and chemistry. In each of these disciplines the science of mathematics may be applied. It is also an experimental science since data which is lacking in the field may be obtained by measurement or experimentation. These data may be integrated at the levels of the individual, population and the ecosystem.

AGRICULTURE, AGROECOSYSTEM AND TECHNOLOGY

Agriculture may be defined as the science, business, art and industry of plant and animal production on the farm. Its main objective is the manipulation of the genetics of crop plants and animals and their environment to the extent that would maximize production of food, fiber and other products. Agriculture is an applied science consisting of many disciplines including Crop Science, Soil Science, Animal Science, Veterinary Science, Agricultural Engineering, Agricultural Economics and Agricultural Extension. Each of these major areas of specialization consists of sub-disciplines such as Soil Physics, Soil Microbiology, Dairy Science etc. The growth and scope of agricultural science is often represented by the development of borderline areas such as crop ecology, agricultural biology and agricultural chemistry. As an applied science, agriculture derives its nutriment from the same basic sciences as does ecology. Agricultural production is therefore the result of interaction among various disciplines and related sciences.

Just as in ecology, an agroecosystem is the agricultural equivalent of an ecosystem. As already defined above, it is a unit of organisms in a crop or animal production area with the overall environmental conditions crop or animal production area with the overall environmental conditions with which they are in contact together as they may be further modified by various activities of man. The agroecosystem represents a portion of the cultural landscape occupied by one or more crop and/or livestock species and representing man's intervention in the natural environment. Modern agriculture is the result of application of science and technology to farming. The extent of modification of the natural environment in agriculture varies with the intensity of human activities, application of science and technology and the duration of these activities. In tropical agroecosystems, man's activities have been limited to what he can accomplish with his own power, a few simple tools and relatively unimproved crops and animals. The tropical agroecosystem is less studied and understood by scientists and agriculturists than temperate agroecosystems. Yet as the natural ecosystems of the tropics are more complex than those of temperate regions, traditional tropical agroecosystems are more complex but to some extent less fragile than modern temperate agroecosystems (Ito, 1973). These traditional agroecosystems are under various pressures of modernization involving changes not much ordered by application of scientific knowledge of the environment and technology or the understanding of its component parts as in temperate agriculture. Its study, understanding and sustained improvement will depend on our success in the basic studies of the tropical environment and the execution of multidisciplinary problem oriented research projects of sufficient scope. Success in tropical agricultural production has somewhat been hampered by attempts at direct application of techniques developed in temperate agriculture.

In agricultural production, the problem of pest control is a manifestation of man's continuing struggle and competition with other organisms for various resources. This despite man's seeming dominant position on earth or as sometimes claimed in the universe. The level of agricultural production and complexity reached by the African farmer represents his level of advancement in the sciences, the arts and technology and interactions among them. While technology contributes substantially to increased agricultural production, the result of careless technology, misuse of resources and some of man's social and political activities have had adverse effects on agricultural productivity. Thus like ecology, agriculture is an applied, integrative and experimental science whose multidisciplinary nature and complexity are not in doubt.

COMPLEXITY AND MULTIDISCIPLINARY NATURE OF PEST MANAGEMENT SYSTEMS

Integrated control as a component of natural resources management involves the integration of ecological knowledge of the components and processes in dynamic agroecosystems. The development of such pest management systems involves (i) the practical analysis of agroecosystems for pest management with emphasis placed on populations of pest species, their competitors, the organisms that prey on them, their main alternative food supplies and the manner in which other elements of the environment modify all these, and (ii) determination of pest population levels under the influence of the agroecosystem and how the influence operates (Adkisson, 1969).

Huffaker (1972) listed the following guidelines for the development of integrated control programs:

(i) Separation of the real pests from those induced by insecticides in the different regions involved.

(ii) Establishment of realistic economic injury levels for the real pests (with all hidden costs adequately considered).

(iii) Separation of the real pests into those which cause intolerable losses (Key pests) from those which cause sporadic damage (controllable by occasional use of insecticides and other measures).

(iv) Identification of the main factors controlling or of great potential value for controlling (e.g. a resistant variety, a natural enemy, a cultural method, or other selective measure) populations of the key pests and measurement of their effects.

(v) Designing and testing of control system based upon the above guidelines in each of the areas where the key pests and for factors are different.

(vi) Modification of the control systems according to conditions and new inputs as the program is developed.

In accomplishing these goals, knowledge of the biology and economics of the whole cropping system, of population dynamics of each pest species, interaction among pest species, their natural enemies, other mortality factors, measures to be taken and economic considerations are necessary (Huffaker, 1972).

The development of effective pest management system(s) entails the bringing together or cooperation of scientists from a wide range of disciplines involving personnel from universities, government, industrial and private establishments in studying complexes of major crops and ecological units (Smith, 1973). Such a program should consist of the following elements in order of their importance.

(i) Obtaining sufficient knowledge of the agroecosystems to establish quantitatively and qualitatively the inter-relationships among the pri cipal pest species and their natural enemies, soil and weather conditions, main crop production processes and economic relationships.

(ii) Establishment of the need to take a control action for the various pest species

(iii) Intensification of research to make it possible to maximize nature's own principal control forces.

(iv) Development of selective pesticides and selective use of conventional ones.

(v) Development of other selective measures not yet broadly proved in practice.

(vi) Lastly, but not the least important, the development of means for implementing the pest control system.

Another measure of the complexity and multidisciplinary nature of pest management involves the consideration of the range of organisms broadly regarded as pests such as insects, mites, nematodes, birds, rodents and other mammals, bacteria, fungi, viruses, mycoplasma, weeds and plant parasites, (Okigbo, 1974). Knowledge about these, their life processes and their environment can only come from contributions of many biological and related disciplines.

An aspect of the multidisciplinary nature of pest management was emphasized by Springett (1973a) who maintained that each pest problem is embedded in a unique environmental matrix, and calls for one particular solution out of an array of possible answers that vary in scientific and technological refinement, in energy input, in acceptability etc. Springett also listed the following constraints in which solution to pest problems must be found - a powerful system of petro-chemical interests, a term-elected system of government (in many African countries shakey one party states or military regimes of uncertain duration), sluggish systems of public administration, commercial systems that impose unfair burdens on primary industries, inadequate systems of farming, and marketing system wide open to manipulations that are not in the public interest. Apart from these problems in pest management, Southwood and Norton (1973) considered economic aspects of pest management strategies and decisions which included yield and quality of farm crops, roles of damage and control cost, pest - injury relationships, pest-yield relationships, pest-quality relationships, pest revenue relationships, control pest relationships, cost-revenue relationships and role of risk considerations.

It is obvious that an effective scheme of pest management for the African farmer based on sound ecological principles must integrate knowledge from various disciplines. Most of this knowledge is lacking and in many of the disciplines specialists do not exist. Government intervention and the activities and interests of social and political institutions at various levels are also involved. And, as pointed out by Springett (1973a) for Australia, there exists in tropical Africa very crude crop protection systems, and little or no modern industrial and technological facilities to device advanced pest management procedures. There is need for development of industrial and technological capabilities related to various strategies of pest management and some refinement in marketing organization and industrial management.

SYSTEMS APPROACH TO PEST MANAGEMENT

The complex and multidisciplinary nature of pest management is also supported by a new development in the last decade or so involving the application of systems - thinking and methodology to pest management and ecological problems. Geier et al (1973) regard systems approach as an all-pervasive approach to complex processes. It facilitates the analysis of limits and validity of knowledge about the system in addition to conceptualization of the interacting processes involved in the form of simulation models. Systems concepts are applicable to complex phenomena involving several disciplines (Dent and Anderson, 1971). It constitutes an integrating framework for detailed study of what superficially may appear relatively simple. Dent and Anderson defined a system as a complex of several discrete but interacting linked factors which interact in a complex manner to produce a specific result when operating in given amounts sequences and timing.

Systems analysis was first applied to military, engineering, industrial, and business operations. It has recently been extended to agricultural production, ecology and pest management systems. Millikan and Hapgood (1967) for example, regard agricultural production as a complex system made up of groups of interacting factors including physical input factors, economic factors, cultural motivational factors, and knowledge factors. An agricultural product such as the yield of a crop is the result of interaction of several inputs operating in such amounts sequences, combinations and timing as to produce a certain quantity of the product. Our management efforts in manipulati the environment aim at maximizing the yield. Pests constitute one of the important factors which affect the quantity and quality of agricultural products. The magnitude of losses due to pests depend on the interaction of various biological and environmental factors which can be quantified and their processes studied.

Systems analysis according to Moomaw and Hedley (1971) involves (i) a statement of the objective of the total system (ii) a quantitative analysis of its components or environment of the system, (iii) listing of the resources of the system (iv) a schedule of components of the system involving activities carried out and measures of their performances and (v) an analysis of the management of the system. A very important aspect of system analysis is the possibility of developing models of the system by simulation techniques and studying their behavior by mathematical or computer techniques. The effectiveness of simulation models depends on how the model approximates the seal situation evaluated in the field. This systems concept has been adopted at IITA and elsewhere in tackling problems of food production. It's effectiveness will very much depend on the success of multidisciplinary studies, analysis and synthesis of tropical agroecosystems and knowledge of the cultural, economic, social and political matrix in which the farmer lives and operates.

Various aspects of the systems approach to pest problems have been reviewed in the National Academy of Sciences of USA publication on Pest Control Strategies for the future (1972) by Carlson & Castle, Headley, Van der Plank, and McNew. Use of an ecosystem model in simulating algal-fly dynamics in a spring community has been reported by Springett (1973b) and the use of systems approach in the development of a program for bark beetles management in the United States was reported by Stark (1973).

Application of systems analysis to pest management in tropical Africa will require not only detailed information on crop ecology but also of traditional agroecosystems in addition to the farmers' environment. It would also require sound biomathematical training for biologists and greater cooperation and interaction among biologists, agronomists, economists, mathematicians etc. than has hitherto happened before.

CONCLUDING REMARKS

The complexity and multidisciplinary nature of pest management based on ecological principles has been stressed. The complicated nature of the processes which interact to make it possible has also been emphasized. It is obvious that in most African countries at present, knowledge is lacking and there is shortage in the number of personnel in various disciplines for the early development of such a program. Yet it is imperative that if we are to avoid the mistakes of the developed countries and if we are to develop a range of intergrated pest control techniques that are economically within the means of the farmer, technically within his ability and adapted to the local social and political climate, it would be necessary for the following to be given due consideration.

1. There should be a reappraisal of our overall scientific educational programs so as to develop programs that increase the depth and widen the scope of training in biology and in related fields. This would facilitate the production of well motivated scientists who are prepared to rapidly bring about

innovations or make discoveries in areas relevant to our agricultural problems.

2. There is need to increase the mathematical or biomathematical aspects of training of biologists so that in their analysis and synthesis of biological phenomena quantitative methods of approach could be easily adopted.

3. It would be necessary at this early stage of our scientific development to avoid isolation of disciplines and specialists. The tendency of such splits to occur in very much marked in young scientists who are interested in emphasizing the importance and uniqueness of their areas of specialization and especially among scientists trained in different educational systems.

4. Efforts should be directed towards reasonable funding and execution of both basic and applied research and encourage greater cooperation and communication between scientists in the biological sciences and applied fields such as agriculture.

5. It is the duty of African scientists to identify gaps in our knowledge and especially give greater emphasis to establishing priorities in the study of our environmental resources and traditional agroecosystems.

6. Scientists should be in the forefront of all activities aimed at increasing interaction among disciplines and in bringing the gap between scientists and non-scientists. It should be emphasized that in the development of pest management systems an informed public and government that is well aware of the importance,

advantages and disadvantages of proposed measures are necessary. An informed public would always see to it that industry in pest control and other activities acts to the public good.

7. Finally, while scientific sophistication is an aspect of advancement in science our scientists should always encourage studies of practical down-to-earth problems related to the needs of our society rather than getting deeply involved in continuing elaboration of their thesis research problems.