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The Sterile Insect Technique and Area-Wide Insect Control or Eradication in the Tropics (**)

SUMMARY. — Tropical agricultural production is characterised by small plots, subsistence farming, shortage of good seeds of the proper varieties, labour-intensive production practices, lack of capital, and lack of major investments in mechanical and production aids. It is in this type of production system that a shift from chemical to biological technologies is being sought.

Chemical technologies can be applied on a field-by-field basis with good results. In the case of insect control, effective use of the appropriate insecticide on a small field will protect that field from insect attack, regardless of whether neighbouring fields are effectively treated. In most cases, field-by-field application of biological technologies for insect control will not be effective. Biological insect control technologies will require an area-wide approach in which all of the fields in a geographical or political area are treated with the biological technology selected. Thus, to successfully implement biological technologies for insect control, a different type of strategy will be required than is commonly recommended today.

The sterile insect technique (SIT) is a biological area-wide control technology which has been successfully applied to eradicate a number of insect species in defined areas. The SIT has not been utilized for insect control, as compared to eradication, and in fact research to utilize the technology for control has not been conducted.

The SIT is a species-specific and environmentally friendly insect control/eradication technology. Its acceptance for use is increasing and as more information is obtained on the strategic use of sterile insects, an increase in its application can be anticipated. Central mass-rearing facilities in developed countries to supply sterile insects for projects in developing countries would hasten the utilization of the SIT.

Inundative release of parasites or predators for insect control, the use of insect pathogens, and varieties of plants resistant to insect attack are most effective when utilized on an area-wide basis.

A serious effort to gradually shift from chemical to biological technologies will require changes in university training, changes in research objectives, more co-operation among farmers, and strong advocates in decision-making positions of organizations responsible for agricultural development aid in tropical countries.

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I. *Introduction*

The green revolution of the 1970s and early 1980s was based on the development of improved plant varieties combined with inputs of fertilizers, pesticides, and in some cases mechanical equipment. The results of this revolution in agricultural production, particularly in Southeast Asia, have been striking. Southeast Asia is reasonably self-sufficient in most basic foodstuffs. Likewise in Latin America there are no severe shortages of basic foodstuffs, due to a large extent to the green revolution. The same cannot be said for Africa, where agricultural shortages are common.

The fact that this international meeting is being held states that there are agricultural production problems in the tropics which have not been solved. The title of the meeting infers that there are problems with the use of chemicals involved with the green revolution and that a shift from chemical to biological technologies would be more friendly to the environment. However, it is certain that chemicals will continue to be the backbone of insect control in the tropics, as elsewhere. The quantities of chemicals used in the tropics will increase. A more rational use of chemicals also will occur, assisted by education at the farmer level. This education must include an understanding of insect problems as well as safe and effective use of chemicals.

Since there are agricultural production problems in the tropics, it would be reasonable to identify the problems and also to identify the reasons for the problems. This is not the subject of the meeting, however a few words might be in order to remind ourselves that, for the most part, the problems are man-made. It is probably safe to say that most of the agricultural production problems in the tropics are a result of government policies, such as pricing, marketing, the absence of adequate extension services, etc. Farmers may be uneducated but they are certainly not dumb and history has shown us that they will adapt new technologies as rapidly as they can if they can make a profit. It is questionable whether there is a lack of technical knowledge in tropical developing countries; extensive technical training has taken place in the last 30 to 40 years. One can probably assume that little of this training has been adequately utilized. The availability of improved varieties of seeds, fertilizers, pesticides, mechanical equipment, etc., all of which require convertible currency, is a limiting factor. However, with adequate profit from the sale of agricultural commodities it should be possible to import these items.

The lack of farmer owned co-operatives to assist producers in obtaining the necessary inputs is detrimental to improved efficiency of agricultural production in the tropics. Farmer owned co-operatives have been extremely valuable aids in developing agricultural production in nearly all developed countries. Co-operatives also should play a major role in safe and rational use of agricultural chemicals, particularly at the farmer level.

Small plots, subsistence farming, shortages of good seeds of proper varieties, labour-intensive production practices, lack of extension service advice, lack of capital, lack of major investment in mechanical and chemical production aids, all are common to agricultural production in the tropics. This type of agricultural production is not the most favourable for starting to shift from chemical to biological technologies, something that has not yet been effectively implemented in the developed countries. However, it may be an advantage that producers in developing tropical countries have not yet developed a great appetite for excessive use of chemical production aids. They may be somewhat more amenable to utilizing biological inputs if supported by appropriate research and development and an effective extension service. However, to achieve this type of rather dramatic change in agricultural production will require a considerable change in the types of strategies developed for insect control. In addition, it will require research with somewhat different objectives than is normally conducted in either developing or developed countries.

II. *Area-wide Insect Control*

Most insect control throughout the world is done on a field-by-field basis. That is, the individual farmer makes a decision, either on his own or with the advice of extension personnel or other advisers, as to when to treat for insect control, what chemicals or other methods to use, etc. In some cases the actual treatment is conducted by the farmer, in other cases it is done by someone who has been employed to do the job. The latter is most common in the developed countries with the former most common in the developing countries. This approach, field-by-field insect control, has proven effective when insecticides are utilized.

Area-wide insect control involves the management of the total insect population of a given species or group of species in a defined area. This area can be a cropping area, geographical area or a political area. It is preferable if the area is limited by geography or by crops planted, however this is not mandatory. Without some sort of isolation, there will be more difficulty in managing insect infestations on the border areas than if there were some degree of isolation. Area-wide insect control should be viewed as preventative insect control for those major key insect pests which normally require insecticide treatment in order to obtain reasonable yields. Control of the pest should take place before it becomes a serious problem in the area under control. Preferably, control technology should be applied when the pest is just building up its numbers on alternate hosts or on a small amount of preferred hosts scattered in the area under control. Area-wide insect control has not been utilized extensively except in situations where governments have assumed the responsibility for control of a particular insect pest, where agricultural production co-operatives working with many producers in a defined area apply control technologies on an area-wide basis, or where no other strategy is effective. Area-wide control has the disadvantage that producers may not have a direct input into the decision-making process and thus view the control procedures as being done for them and not by them. Agricultural producers, being somewhat more individualistic than other groups in society, tend to dislike this approach. On the other hand, the control of such insects as locusts, black flies and tsetse flies requires an area-wide approach. Unfortunately the strategy of insect control on a field-by-field basis is deeply embedded in our educational system. Thus, although many insect species are amenable to area-wide control, scientists and administrators frequently do not think in these terms.

Examples of area-wide control utilizing insecticides include olive fruit flies, locusts, mosquitoes, black flies and tsetse flies. Utilizing biological control methods, the cassava mealy bug is being attacked on an area-wide basis by parasites released into a very large area in Africa. In addition, the use of *Bacillus thuringiensis* for control of the black flies is being developed and used in the onchocerciasis programme. Genetic control has been developed and used against several species of the tsetse fly, Mediterranean fruit fly, screwworm fly and certain other species of insects. It is reasonable to assume that other insect species will become the target of the sterile insect technique in the future as additional research and development is conducted and as the advantages of the technology are more widely understood. Host-plant resistance, a genetic method of insect control, is not generally considered an area-wide method of control. However, in many parts of the world, the extensive use of plant varieties which are resistant to insects certainly is a method of area-wide insect control.

The inundative release of parasites or predators, pheromones or other behaviour modifying chemicals, also should be approached on an area-wide basis, using a preventive strategy, as for the SIT. Inundative release of parasites and predators nearly always requires an area-wide approach. These biocontrol agents will not stay only in the field where they are released, unless that field is the only source of host material. Neither the SIT nor parasites nor predators act rapidly in reducing insect populations. Thus the efficient use of these biological technologies requires an area-wide basis and optimally a preventive strategy within the area under control.

III. *The Sterile Insect Technique*

The sterile insect technique (SIT) has been developed during the past 30 years. It is currently available for use, or is being used, against a number of insects, primarily Diptera. Included are the screwworm fly, Mediterranean fruit fly, Mexican fruit fly, melon fly, onion fly, and several species of tsetse fly. The technology is used as a quarantine to prevent the establishment of the pink bollworm in non-infested areas in California. Considerable research and development is being devoted to utilizing the technology against other insect species.

There are a number of characteristics of the SIT which should be kept in mind. The technology is species-specific and thus is used only against insect species which are major pests. The SIT has no detrimental effect on beneficial insects, must be applied on an area-wide basis (thus it is not applicable for use by the individual producer), has been developed primarily for use against Diptera, and has been used primarily in eradication campaigns rather than control campaigns.

Factory-size insect mass-rearing facilities are required; the product of these factories, insects, must meet certain quality standards.

The SIT is more effective against low populations of insects rather than high populations. The reverse is true of insecticides. In the case of insects, a single application of the recommended dosage of the insecticide will usually kill 90% of the insects in the treated area. This 90% kill does not depend on the population of insects present. Thus if there are 1,000,000 insects present, an insecticide application will kill 900,000 and leave 100,000 survivors. If the insect population in the area is 100,000 insects, 90,000 will be killed and 10,000 will survive. A SIT treatment at the recommended dose (release rate of sterile insects) is much more effective when few insects are present because the ratio of sterile males to wild males is much higher when fewer native insects are present. Thus in the case of an insect population of 1,000,000 which is treated with sterile insects at a dosage of 4,000,000 sterile males, the chances of any population reduction are very slim since the normal rate of increase of most insect species is 4 to 5-fold per generation. However, if the native insect population is 100,000 and the same dosage of sterile insects is released, the ratio of sterile males to native males will be 40:1, which will result in a drastic reduction of the native population in the following generation. Thus the SIT is used when insect populations are naturally low or after they have been reduced by other control technologies.

One final characteristic of the SIT, which is also characteristic of most biological control technologies, is that the total research and development costs are borne by public-funded organizations. Commercial concerns invest heavily in the development costs of new insecticides. In addition, the practical application of the SIT is almost entirely conducted by publicly-funded organizations, whereas commercial interests frequently become directly involved in the application of insecticide technology. Commercial companies should be encouraged to critically review the potential of the SIT as a profit-making activity.

The SIT requires the large-scale production of good quality insects, sterilization (usually by irradiation), and release into the target area. The sterile males mate with the wild females and prevent reproduction. The SIT is in effect birth control of insects. The quite simple mathematical models of insect populations developed and used by Dr. E.F. Knipling to base his initial theoretical use of the SIT have proven accurate. Although many people consider the SIT applicable only for eradication, it is being used, as mentioned above, for quarantine purposes. There is no particular reason why it cannot be used for control where the mass-reared, sterilized and released adult insect causes little or no damage. The use of the SIT for control of the Mediterranean fruit fly has not been seriously considered because of the damage caused by the released female medflies; the female punctures fruit in an effort to lay eggs. These punctures blemish the fruit and sometimes result in invasion of micro-organisms which further reduce the quality of the fruit. The producer thus receives less money for his product. If only male medflies could be released, this "sterile sting" problem could be alleviated and the technology would be applicable for control as well as for eradication.

The FAO/IAEA research programme, conducted at the IAEA laboratory, includes research to develop a genetic strain of the medfly in which all females can be killed in the egg or neonate larval stage. The successful completion of this research will result in the capability to release only sterile males.

Co-operative research between scientists in Italy and the IAEA has indicated that in addition to eliminating the sterile sting problem, the release of only or predominantly sterile males increases the efficacy of the SIT. Presumably this increased efficacy is because of the elimination of sortative mating, in which the laboratory males and females prefer to mate with each other rather than with the wild medflies.

The SIT is an example of area-wide control which is effective and has economic and environmental advantages. In situations where area-wide insect control is applicable, and during the very early crop growing season, when the pest species occurs either in a very limited portion of the area or on a sparse population of alternate hosts, the use of the SIT should prove extremely effective. The sterile insects would be released early in the growing season, before the crop to be protected is susceptible to insect attack. By reducing the birth rate of the pest species before it attacks the major crop, the numbers of the pest species which reach the major crop will be greatly reduced and may require no additional control procedures. To achieve this type of control it is necessary to have good knowledge of the population dynamics and ecology of the pest species. This type of strategic preventive insect control on an area-wide basis must be the subject of considerable research and development effort if there is to be a shift from chemical to biological methods of insect control.

Other types of genetic control which show promise include inherited sterility (sometimes called F1 sterility), hybrid sterility, use of translocations and compound chromosomes, and insect strains refractory to disease transmission.

The mass-rearing of insects for SIT programmes, and for inundative release of parasites and predators, is a manufacturing process. Methods of shipping insects over long distances and up to a total time of 24 or more hours have been satisfactorily developed. Quality control factors have been developed in some cases and are currently being used. These factors permit the writing of specifications for the quality of the insects which are used in a programme.

One of the inherent difficulties with most SIT programmes is that the manufacturing process (mass-rearing) and the use of the product (i.e., the strategy of utilizing the sterile insects most effectively in an eradication or control programme) compete for the attention of the project management. In SIT programmes the manufacturing process frequently is less well understood and thus receives too much attention at the expense of the strategic use of the sterile insects. In situations where the mass-rearing facility is remote from the site of use of the sterile insects, this problem is greatly reduced.

Therefore serious consideration should be given to construction of insect mass-rearing facilities on a regional basis; mass-rearing of insects for SIT probably would be the first to be considered; however, eventual consideration should also be given for parasites and predators to be used in inundative release programmes. It certainly would be feasible to consider erecting such facilities in Europe. This would permit much more flexibility in design construction, permit the implementation of mass-rearing improvements more rapidly, and probably reduce the total cost of mass-reared insects because of the use of labour-saving devices.

Such a facility would be of enormous value for medfly SIT programmes in the Mediterranean region. Airplane connections are good for transport of the sterile insects, distances are relatively short, there is good technical expertise available to design and manage such a mass-rearing facility, and most important, there is a very real interest in a number of developing countries in the Mediterranean basin to utilize the SIT for medfly eradication. This could be a commercial enterprise.

IV. *Small Plots and Area-wide Control*

The small plot agricultural production systems in most of the tropics make field-by-field insect control difficult. If one small producer does not treat his crop to prevent insect damage, the insects produced in his small field can infest a large number of other fields in the area. Thus, for the field-by-field approach of insect control to be effective, all producers must effectively control the insects in their fields. This means dealing with a large number of individual producers, some of whom may be reluctant, for some reason or other, to treat their fields.

Area-wide control offers a solution to handling major insect pest problems under small plot agricultural production practices. Farmer co-operatives can be very effective and should be encouraged to work towards developing area-wide insect control.

V. *Research and Development Needs for Area-wide Control*

At the present time area-wide control is almost always applied only as a last resort, i.e., when field-by-field control is not effective. Research aimed specifically at determining which major insect species would be susceptible to control on an area-wide basis would be invaluable. Area-wide control will be less expensive in most cases than field-by-field control, particularly when it can be applied before the insect attacks the crop to be protected. However, our knowledge of insect ecology, as well as effective biological methods of insect control to use in these strategies, is negligible. It certainly will be found that this approach would not be suitable for some insects. However, there is little doubt that with many of the major insect pest species the area-wide approach where the control is applied before the insect pest attacks the crop to be protected, would be inexpensive and encourage the use of biological technologies such as the sterile insect technique, inundative release of parasites and predators, etc. If insecticides are used appropriately with this strategy, resistance could become less of a problem because fewer generations of the insect would be subjected to insecticide control on an annual basis.

VI. *Conclusions*

The sterile insect technique has been demonstrated to be an effective method of insect eradication which is cost-effective and environmentally friendly. To date it has been used primarily for eradication. In the future, it will be utilized for control as well as eradication. The SIT will be particularly effective in strategies utilizing preventive insect control on an area-wide basis. The development of the technology is well advanced for many insect species. The requirements for foreign exchange are minimal. The technology can be either high-tech or labour-intensive; many developing countries have policies of full employment and labour-intensive and simple technologies are thus politically acceptable. The concept of eradication of an insect pest is controversial; however, there is no doubt that the successful eradication campaigns to date have improved agricultural production.

Quarantine to prevent the introduction of new pest species is becoming a much more important facet of national agricultural policies as exports and imports of fresh produce increase. These policies will require more emphasis on area-wide insect control, including the sterile insect technique, eradication, and in general, will have an enormous impact on insect control technologies. Research entomologists, administrators of plant and animal protection organizations, and those individuals who make decisions with regard to funding of entomological research, should be aware that there will be very significant changes required in the approach to insect control over the next 20 years. The university systems which teach entomology, insect control and general agricultural production must adapt. Quarantine, area-wide control and inspections of agricultural commodities in the exporting countries by representatives of the importing countries, the need for immediate action to eradicate a newly imported insect pest, all must be part of the curriculum of universities teaching entomology. Producers will have no market for their produce outside of their own country without more stringent insect control procedures.

In conclusion, area-wide insect control using biological technologies, including the sterile insect technique, other genetic insect control procedures, inundative releases of parasites or predators, and insect pathogens, can become a vital factor in agricultural production in the tropics during the next two decades.