STERILITY PRINCIPLE FOR INSECT CONTROL OR ERADICATION

REPORT ON THE JOINT FAO/IAEA SYMPOSIUM HELD IN ATHENS, GREECE, FROM 14 TO 18 SEPTEMBER 1970

The Symposium held in Athens, Greece, from 14 to 18 September 1970, jointly organized by the International Atomic Energy Agency and the Food and Agriculture Organization of the United Nations, was attended by 89 participants from 39 nations and representatives of six international organizations. The Symposium was held against a backgroun of mounting interest and concern throughout the world with regard to the relative merits and economy of various methods of insect control to protect agricultural production and public health. There was general agreement that continuing reliance on pesticides for insect control has numerous disadvantages. However, there was also a clear-cut appreciation that while alternative methods of insect control are drastically needed they have not been developed to an extent that they can be immediately implemented in previously pesticide-oriented insect control programs.

The sterile-insect release method is one of the most advanced non-pesticidal methods of pest control. In its simplest form the method involves the rearing, radiation sterilization and release of massive numbers of sterile insects to compete with the wild insects for mates. Every female in nature that mates with a sterile male does not produce any progeny. As the number of matings with sterile males increases the potential size of the next generation of insects decreases. This approach, continued for several generations, can provide excellent control against agricultural and public health pests and can also lead to the total eradication of a species, as was demonstrated with the screw-worm fly in the south-eastern United States over a decade ago.

Although insect control in agriculture and public health is often given a low priority, the statement by His Excellency Mr. Papavlachopoulos, the Greek Minister of Agriculture, in opening the Symposium clearly indicated the importance of the subject: "Our era is characterized by technological progress and scientific achievement. Nevertheless, the ghost of hunger remains as menacing as ever. A large percentage of the earth's present population of 2.3 billion either are underfed or use food with inadequate vitamin and protein content." In opening the Symposium on behalf of the Directors General of the IAEA and FAO Dr. M. Fried, Director of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, said: "We can see that alternative methods such as the application of the sterile-insect release method for the control of many agricultural and public health pests is not being implemented fast enough. Progress has been made; however, as long as insects remain our first-rank competitors for food and fibre and continue to transmit disease to man and his livestock, additional progress is drastically needed. To many, economical and efficient control of insect pests may seem a minor problem in comparison with the current major scientific issues of population explosion and environmental contamination. However, let us

not forget that all of these are intimately interwoven. The majority of the world's people can ill afford to share their meagre agricultural resources with insect hordes, and the minority of people who are well-fed and healthy are becoming dubious about the continuing reliance on pesticides."

The Symposium was organized in eight sessions. The opening session, entitled "Studies in radiation sterilization of insects", was chaired by Dr. M.E. Tzanakakis of Thessaloniki University, Greece. In the opening paper Bushland (United States of America), a pioneer investigator in this field reviewed developments from the earliest screw-worm experiments up to the present time. It was only 15 years ago that the sterile-insect release method was tested on a large scale on the island of Curaçao for eradication of the screw-worm fly. This successful trial led in 1958-59 to the use of the sterility principle to eradicate the screw-worm fly from the entire south-eastern United States. The large-scale program agsinst the screw-worm fly in the south west was started in 1962, and has been an enormous success. In the past 10 years hundreds of species of insects have been studied with the eventual aim of applying the sterile-male technique. Significant advances have been made in insect mass-rearing technology, and in the use of ionizing radiation and chemicals to induce sterility. An impressive number of field trials have demonstrated that the sterility method was indeed promising for the control of many insect species, yet much additional work and development remains to be done before we can actually point to new and successful large-scale control programs of undeniable importance to agriculture or public health. Bushland discussed in depth the problems encountered with radiation sterilization of certain insect species and their possible solution. With the cotton boll weevil, for example, the dose of radiation which completely sterilized the males led to the death of all irradiated weevils in 10 to 12 days. For this species the application of the sterility principle would probably involve the sterilization of weevils by feeding a diet adulterated with a sterilizing chemical. The release of the sterile insects would follow co-ordinated population-suppression techniques such as late-season insecticide applications and trapping of adults with sex-lure traps in the spring followed by the release of sterile males.

With the radioresistant Lepidoptera which require very high doses of radiation to induce complete sterility in the males it was commonly found that fully sterilized males lack competitiveness. Not only were the males less effective in mating and transferring sperm but often their sperm is not competitive. One recent discovery in Lepidoptera radio-biology might prove to be an actual bonus effect in the application of the sterile-male technique. This finding was that lepidopteran males given a partially sterilizing dose of radiation (permitting 40-50% of eggs fertilized by their sperm to hatch) produced a reduced number of progeny which were more than 90% sterile. This phenomenon of "inherited partial sterility" permits greater competitiveness of released males treated with a lower dose of radiation plus the introduction of sterile adults in the next generation who could negate the reproductive potential of fertile wild moths. Since the insect order Lepidoptera includes some of the world's most damaging species (codling moth, rice-stem borer, sugar-cane borer, corn earworm, fruit worms etc.) the eventual application of the sterility principle to control these pests would constitute a great leap forward in agriculture.

Bushland discussed many other modifications of the sterility approach that were currently in the developmental stages. One of these involved the use of a monogamy factor in insect control. This chemical, which is transmitted by the male to the female at the time of copulation, thereafter elicited a biochemical and physiological response in the females which prevents them from undertaking further matings. If in the future this chemical or a related compound can be produced, a species-specific pesticide which reduces insect populations by preventing mating of female insects would be available.

The first session also contained papers reviewing the effect of radiation on the gypsy moth, an important forest pest in many areas of the world, and on insects affecting fruit and stored grain.

During the second session chaired by Dr. E.A. Taylor (United States of America), two survey papers, by Taylor and by Mellado (Spain), on work on the Mediterranean fruit fly, clearly showed that in the past 10 years a great amount of research had been devoted to applying the sterility principle to this pest. Field trials in Central America, Spain, Hawaii and Italy had shown that the sterility principle was extremely effective against this species. Other fruit flies discussed during this session included the cherry fruit fly, the olive fly, and Anastrepha species. Indeed, it appears that fruit flies which menace production of all kinds of fruit in practically every area of the world are prime candidates for application of the technique. Recent innovations in the mass rearing of such insects have shown that they can be reared in millions at relatively low cost. With radiation from cobalt-60 insects can be effectively sterilized by exposures to low doses. Several field trials have shown that the released sterile insects, while not fully competitive with the native wild insects, would drastically reduce the population. Extension of this technology to the olive fly was still limited by problems in mass rearing.

A third session, chaired by Mr. J.W. Wright of WHO, was devoted to the sterility principle for the control of insects affecting man and animals. Most of the papers dealt with several species of tsetse flies, mosquitoes, and triatomid species (vectors of Chagas' disease in Central and South America). A survey paper by Jordan (United Kingdom) discussed the recent advances in mass-rearing tsetse flies. A few years ago these insects could not be reared in captivity. This prohibited the research needed to develop sterile-insect techniques for control of this pest and curtailed many other programs. Recent findings have shown that several species of tsetse flies can be easily reared in the laboratory. However, experimenters still had to rely on the use of live hosts such as rabbits or cattle to feed the flies.

Further advances in the artificial rearing of tsetse flies and other blood-sucking insects were discussed in another session chaired by Dr. T. Jermy (Hungary). Rachel Galun (Israel) presented a survey paper on "Recent developments in the biochemistry and feeding behaviour of haematophagous arthropods as applied to their mass rearing". Mews, of the IAEA Seibersdorf Laboratory, presented a paper on "The maintenance of Glossina morsitans on membranes". These two papers indicated that it was very likely that in the future blood-sucking insects such as tsetse flies and mosquitoes could be reared on artificial membranes probably using freeze-dried blood. This would constitute a major step forward in the artificial rearing of blood-feeding insects and considerably reduce

the cost of rearing large numbers of arthropods for use in release or research programs. Other papers presented in this session, dealing with basic biology and the artificial rearing of insects, were concerned with various lepidopterous pests, the fruit fly, the olive fly, and in particular the rearing, ecology and radiation sterilization of the onion fly.

During the session on "Chemosterilization and reproductive physiology" chaired by Dr. Rachel Galun (Israel), Landa (Czechoslovak Socialist Republic) presented an historical review, "Effects of chemosterilants on reproductive organs and embryogenesis in insects". The large number of papers presented in this session bore testimony to the extensive amount of research on insect chemosterilants during the past few years. Numerous chemicals had been tested for their sterilizing effects on no fewer than 60 insect species of economic and public health importance. Although numerous chemicals were very effective, none of these at the present time appeared to be applicable under area-wide situations. Most of these chemicals were not insect-specific in that they produced similar effects in insects and mammals. Nevertheless, insect chemosterilization remained an intriguing possibility, mainly because of the hope that it would be feasible to combine a sterilizing chemical with a powerful insect attractant. Insect control could be attained by attracting the insects to a centralized treatment location exposing them to the chemical sterilant by either feeding or contact with a treated surface. The insects could be effectively sterilized and released into the environment. This would remove the need for mass rearing of large numbers of insects, sterilizing them and releasing them into nature. Although this was not fully developed for large control programs at the present time, several field tests conducted on mosquitoes, tsetse flies and house flies have shown that in the future this approach to insect control might be feasible. A great amount of interest was shown in this subject at the symposium.

During the session on "Sterility principle for insects attacking food and fibre crops", chaired by Dr. L. Mellado (Spain), Adkisson (United States of America) refuted the erroneous idea that the sterile-insect release method was not applicable to species with a wide host range. His data on the population dynamics of the bollworm, Heliothis zea, an insect which had many hosts, showed that multi-host insects might indeed be very vulnerable to control or eradication by the sterility technique. Data were presented that showed that the Achilles heel of multi-host insects lies in the violent fluctuations in their numbers, from very high to very low, that occurred several times each season. Adkisson stated that adequate studies on population fluctuations on each host plant could in most instances clearly indicate the proper timing and location of sterile-insect releases for maximum population suppression at minimal cost. Jermy (Hungary) presented a survey paper on "Genetic control experiments on Acanthoscelides obtectus". The concept of genetic control mechanisms for a variety of insect species represented a new modification or, let us say, an offshoot of the sterility principle for insect control or eradication. Basically, the use of chemicals or irradiation to induce sterility in insects relies on the induction of genetic damage in the reproductive cells of males or females which prevents the egg or sperm from producing an offspring. Many different genetic mechanisms are known in insects which produce the same effect and they are being developed for insect control. In the early days of the sterile-male technique it was considered that the released

insects had to be totally sterile. This concept, while still valid, is being modified by new concepts which consider either the release of males which are not fully sterile in order to increase their competitiveness in the wild, or the introduction of genetic factors into an insect population which will adversely alter its reproductive potential, immediately and in the future. Basically, this approach involves the introduction into the wild population of various genetic deficiencies or changes which are expected to reduce the reproductive potential of a population. These "genetic mechanisms of insect control" were the subject of a session chaired by Dr. A.M. Jordan of the United Kingdom. In his survey paper Milani (Italy) discussed "Genetics of sterility factors and sex-ratio distortion in house flies". Other genetic control mechanisms which were discussed included the use of chromosome re-arrangements and translocations for mosquito and tsetse fly control and the use of induced conditional lethal mutations for insect control in general. This session on genetic control mechanisms proved to be one of the livelier ones of the symposium. Much of the discussions centred upon whether it was better to release fully sterile males to compete with native males or to use males either homozygous or heterozygous for chromosome translocations. The use of chromosome translocations is generally acknowledged to have a lower effect on the reproductive potential in the next generation following release. However, it has the added advantage over the full sterility technique that many of the progeny of the released males were totally or partially sterile. The general conclusion was that in practice the genetic control method selected had to be considered in relation to the insect species against which it would be applied. It was generally agreed that a particular genetic control approach which might be extremely effective against a certain insect species would probably be less effective against another insect species which had a totally different ecology, population dynamics and intrinsic rate of population increase.

The closing session, on insect radiobiology, was chaired by Dr. J. Itard of France. Some topics discussed during this session involved the use of nitrogen during irradiation to increase competitiveness of sterile males, computer models for efficient control of insect populations by the sterile-insect release method, and inherited partial sterility for control of lepidopterous populations.

Throughout the symposium many of the speakers acknowledged that in spite of the difficulty in obtaining funds for the conduct of preliminary field trials much progress had indeed been achieved. Several speakers pointed out that a single successful large-scale field demonstration would be a greater impetus to pest control by this method than the study and sterilization of half a dozen new species in the laboratory. In principle the sterile-insect release method is applicable to any sexually reproducing insect species. However, field control programs require a high initial expenditure of funds and a smoothly efficient organization of experienced scientists and technicians, whereas laboratory research is more easily within the reach of the individual scientist.

The complete proceedings of the symposium have been published in Vienna by the International Atomic Energy Agency at the price of $14.

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